Water-Supply and Irrigation Paper No. 216

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES

OF THE

REPUBLICAN RIVER VALLEY

AND ADJACENT AREAS, NEBRASKA

BY

G. E. CONDRA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1907

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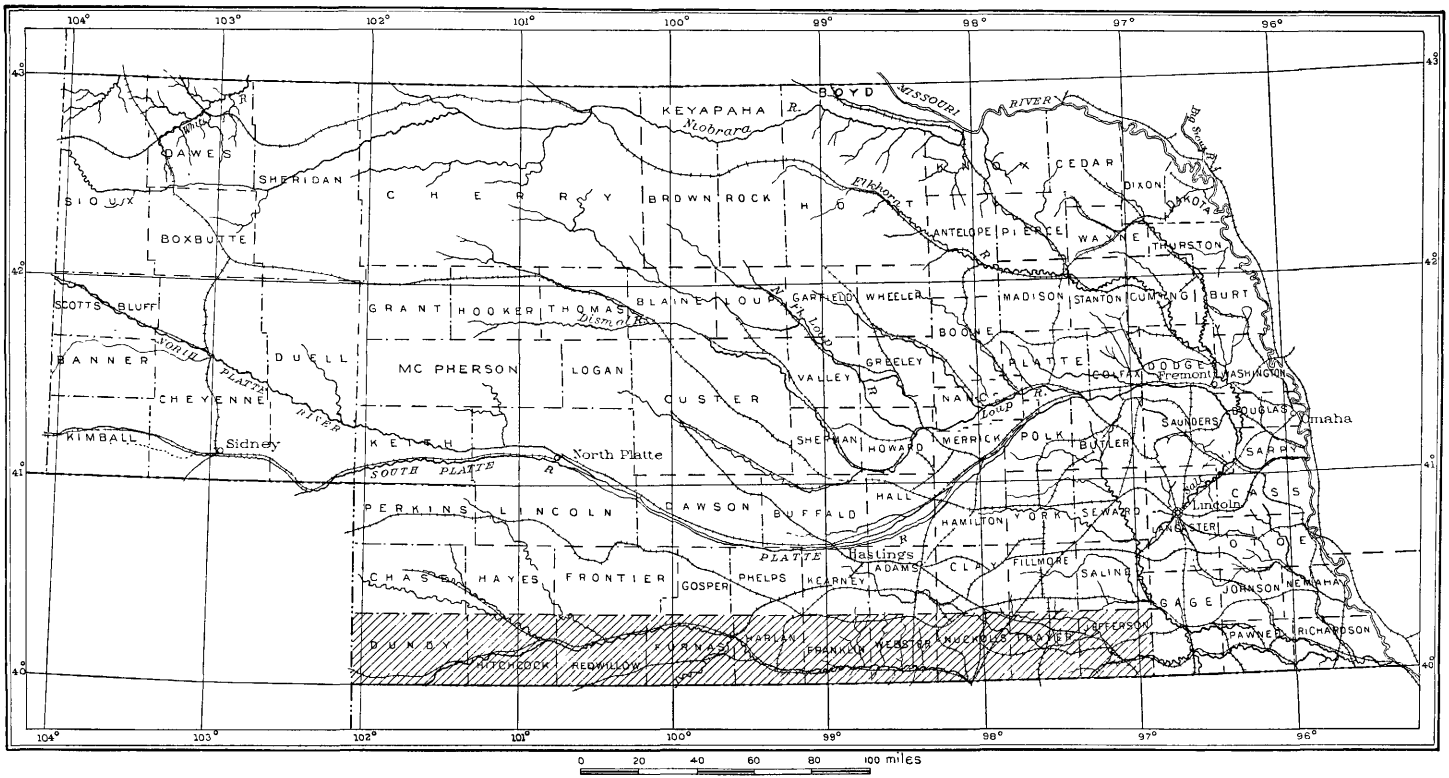

MAP OF NEBRASKA, SHOWING AREA TREATED IN THIS REPORT.

GEOLOGY AND WATER RESOURCES OF REPUBLICAN RIVER VALLEY AND ADJACENT AREAS NEBRASKA.

By G. E. Condra.

INTRODUCTION.

The region described in this report is the portion of southern Nebraska lying between latitude 40° and 40° 20′ and longitude 97° and 102°. It is 22¾ miles wide and 272½ miles long, and comprises an area of about 6,199 square miles. As shown in Pl. I, it includes the greater part of 10 counties, which are, from east to west, Jefferson, Thayer, Nuckolls, Webster, Franklin, Harlan, Furnas, Redwillow, Hitchcock, and Dundy. They lie along the Kansas border, extending from the vicinity of Fairbury westward to the Colorado State line.

This report is the result of general observations made during several consecutive seasons and of special field studies made by the writer under the direction of N. H. Darton during the summer of 1904. Considerable information concerning this region, collected by the Nebraska geological survey, has been furnished by Prof. E. H. Barbour. Numerous well records have been given by well drillers, business men, county superintendents, and teachers. The writer is also indebted to Messrs. U. G. Cornell, George A. Loveland, J. C. Stevens, E. N. Averill, N. J. Allen, and F. A. Carmony for valuable information.

Topographic maps are available for a portion of this area, the following sheets having been published by the United States Geological Survey: Hebron, Superior, Red Cloud, Holdrege, and Arapahoe. The topography for the remainder of the area has been compiled from barometer readings and railroad data.

GEOGRAPHY.

TOPOGRAPHY.

The area covered by this report is part of the Great Plains. It extends over portions of three fairly distinct physiographic regions—the high plains or table-lands, the loess plains or prairies, and the sand hills, each region possessing characteristic topography and drainage.

The general slope of the higher plains or upland surface is eastward from an altitude of about 3,600 feet in the western part of Dundy County to about 1,400 feet in the eastern part of Jefferson County, at an average rate of about 8 feet to the mile. The lowest altitudes are along the valleys in Jefferson County, being less than 1,250 feet south of Steele City. In most of the area, except in the sand hills, the topography has been developed by the action of running water, but in Jefferson County the great ice sheet of the Glacial epoch was an important factor in shaping the surface and developing its drainage.

The loess plains are relatively smooth and in greater part have practically no surface drainage, but where they are cut into by water courses there are deep canyons bordered by precipitous walls. Some of these canyons are long and deep, notably Trail Canyon, 4 miles east of Haigler, where there is a fall of 300 feet in a distance of less than 2 miles.

The sand hills, which are an outlying area of the great sand-hill region of Nebraska, extend from the north-central part of the State to its southwestern corner. The largest district treated in this report is in Dundy County north of Republican River and west of Rock Creek. The characteristic topographic forms are rounded sand dunes, sand ridges, blow-outs, dry valleys, and basins, with no run-off water except at the edge of the hills. Water often collects in some of the basins during the rainy season, forming small lakes.

DRAINAGE.

The principal streams in the area are Republican and Little Blue rivers. The course of the former corresponds in direction with the general eastward slope of the country. Its bed lies 200 to 400 feet below the bordering uplands, and its valley slopes, though generally rough, vary somewhat in character from place to place, according to the varying nature of the geologic formations which the stream traverses. The valley itself and the valleys of the tributaries are generally wide and bordered by a definite system of terraces.

The valley of Little Blue River is nearly as wide as that of the Republican, but is somewhat shallower, and its direction is diagonal

to the general eastward slope of the surface. Near Powell it turns southward at right angles to its first course, a change possibly due to the former presence of the glacier in this vicinity.

CLIMATE.

TEMPERATURE.

The mean annual temperature in Jefferson County and in most of the region as far west as Hitchcock County is about 51°, but farther west it decreases to an average of 50°. The warmest month is July and the coldest January. East of Furnas County the number of days without frost during the year varies from 155 to 165. The latest frost of spring occurs between April 25 and May 1, and the first frost of autumn about October 1. In Furnas County and the remaining area to the west the average number of days without frost varies from 145 to 150. The latest frosts of spring occur between May 1 and May 5, and the earliest of autumn between September 25 and October 1.

RAINFALL.

The average annual rainfall at eight stations is shown in fig. 1. The stations are located at regular intervals from east to west across the area, but the time during which records have been kept at the different stations varies in length from eleven to twenty-eight years. The heaviest rainfall is in May, June, and July, with light precipi-

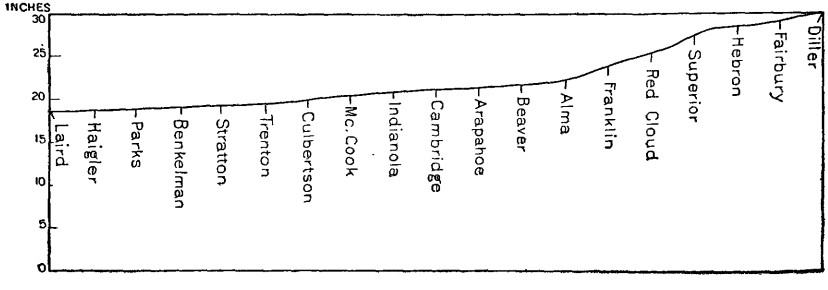

FIG. 1.—Diagram showing the decrease of mean annual rainfall from east to west in southern Nebraska.

tation during the winter months. The snowfall is slight, especially in Dundy County, but farther east it increases somewhat in amount. In the summer occasional hailstorms occur throughout the region, but are most frequent in the western portion, where they often do considerable damage to crops. Cloudiness is greatest in the east, giving way in the west to increasing sunshine and a lower degree of humidity.

Normal precipitation, in inches, at eight stations in southern Nebraska.

Place.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Fairbury	0.75	0.74	1.63	2.75	4.74	4.61	4.80	3.13	2.45	2.38	0.79	0.63	29.40
Hebron	.77	.68	1.46	2.62	4.69	4.74	4.38	3.48	2.37	2.14	.96	.66	28.95
Superior	.57	.78	1.06	2.98	4.00	4.31	4.92	2.82	2.36	2.24	.72	.57	27.33
Red Cloud	.33	.59	.77	2.27	3.32	4.75	4.30	2.73	2.77	1.81	.59	.51	24.74
Franklin	.42	.63	.89	2.48	3.86	3.53	3.34	2.87	2.82	1.90	.42	.45	23.61
Beaver	.25	.62	.77	2.48	3.18	3.90	3.60	2.28	2.03	1.14	.54	.41	21.20
Culbertson	.37	.63	1.05	2.36	2.76	3.56	2.94	2.74	1.52	1.05	.36	.36	19.72
Haigler	.19	.39	.81	2.01	2.99	2.78	2.91	2.73	1.21	.77	.43	.26	17.48

WINDS.

No reliable data are available as to wind velocity, but the wind is generally stronger in the western counties than in those farther east.

DESCRIPTIVE GEOLOGY.

GENERAL RELATIONS.

Southern Nebraska is underlain by various formations of Cretaceous age lying unconformably on Carboniferous formations and extensively overlain by Tertiary and Quaternary deposits; originally the latter covered the entire surface, but they have now been removed in the deeper valleys.

The relations underground of the Cretaceous formations have been revealed by deep well borings. They are of sedimentary origin, consisting of shale, sandstone, limestone, and chalk, and lie nearly level in a succession of widespread sheets. In the western part of the region they reach a thickness of 4,000 feet or more, but owing to erosion they thin out to the east. The Tertiary and Quaternary deposits consist of sands, loams, clays, bowlders, calcareous grit, and sandstone.

The formations outcropping in this area are as follows:

- Quaternary
  - Dune sands.
  - Alluvium.
  - Loess.
  - Drift.
- Tertiary
  - Ogalalla.
  - Arikaree.
- Cretaceous
  - Pierre.
  - Niobrara.
  - Benton:
    - Carlile.
    - Greenhorn.
    - Graneros.
  - Dakota.

Base compiled from U.S. Geological Survey atlas sheets and from field sketches

GEOLOGIC MAP OF REPUBLICAN AND LITTLE BLUE VALLEYS IN NEBRASKA

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Scale

The distribution and general structural relations of these formations are shown in Pls. II and III. The oldest is the Dakota sandstone, which underlies all of the region discussed, and is in turn underlain unconformably by Permian limestones and shales which outcrop extensively farther east in Nebraska and southeast in Kansas. The overlying formations occur in regular order, but do not extend over the entire area.

STRUCTURE.

In southern Nebraska the rocks lie nearly horizontal, but, as shown in the section on Pl. II, with a general westerly inclination, interrupted near Cambridge by a low uplift or arch discovered by Mr. Darton several years ago. This arch develops in northwestern Kansas and extends northwestward across Nebraska. Its configuration is defined by the relations of the Niobrara formation, which is uplifted 200 feet or more near the crest of the arch in the vicinity of Cambridge. From the crest the Pierre shale and 100 feet or more of the Niobrara have been eroded in the central and western portions of Furnas County. On the west side of the anticline the strata dip westward at an unknown but moderately rapid rate, so that in the extreme southwestern corner of Nebraska the top of the Niobrara formation is at a depth of about 2,000 feet, judging by the structure in adjoining portions of Colorado. East of the anticline there is a shallow syncline which holds Pierre shale from Arapahoe east to Naponee; thence eastward the strata rise gradually, and formations from Niobrara to Dakota outcrop in regular succession in the counties from Franklin to Jefferson. In general the rate of inclination is regular and averages 3 feet in a mile. Locally, however, the rate is very much increased, especially in portions of Jefferson County. A local flexure is presented by the Greenhorn limestone in the southern portion of Jefferson County, and steep local dips of 10° or more occur to the southwest, in the exposure of Dakota sandstone south of Thompson, Nebr. The Dakota formation presents also a low anticline in the vicinity of Thompson and Gladstone, with the upper part of the arch removed by erosion. Faults, showing a few inches of displacement, occur in the Niobrara chalk in a number of places, one of the best defined examples being at Norton in beds dipping gently westward. This fault is shown in Pl. IV, *B*.

DESCRIPTION OF THE ROCKS.

CARBONIFEROUS SYSTEM.

A short distance east of Jefferson County Permian limestones and shales—the upper series of the Carboniferous system—rise from

beneath the Dakota formation and appear in many outcrops. They undoubtedly underlie the area treated in the report but at increasing depth to the west, and it is possible that they immediately underlie the alluvium in the vicinity of Diller and along the Little Blue River Valley below Steele, where they are known to come close to the surface. The following is a typical section of the Permian beds which pass under the Dakota sandstone in southeastern Nebraska:

Section at the J. P. McAllister quarry, 1 mile southeast of Odell.

	Feet.
Limestone, fossiliferous, weathered	⅔
Clay, light buff	4
Limestone, grayish, but rusty at places, massive, even grained, with few fossils; used for building stone	1½
Clay, buff colored	4
Clay, ocherous, reddish to brownish	12
Limestone, clayey, decayed	5
Limestone, flinty	1½
Clay and decayed limestone, exposed in ravine	?

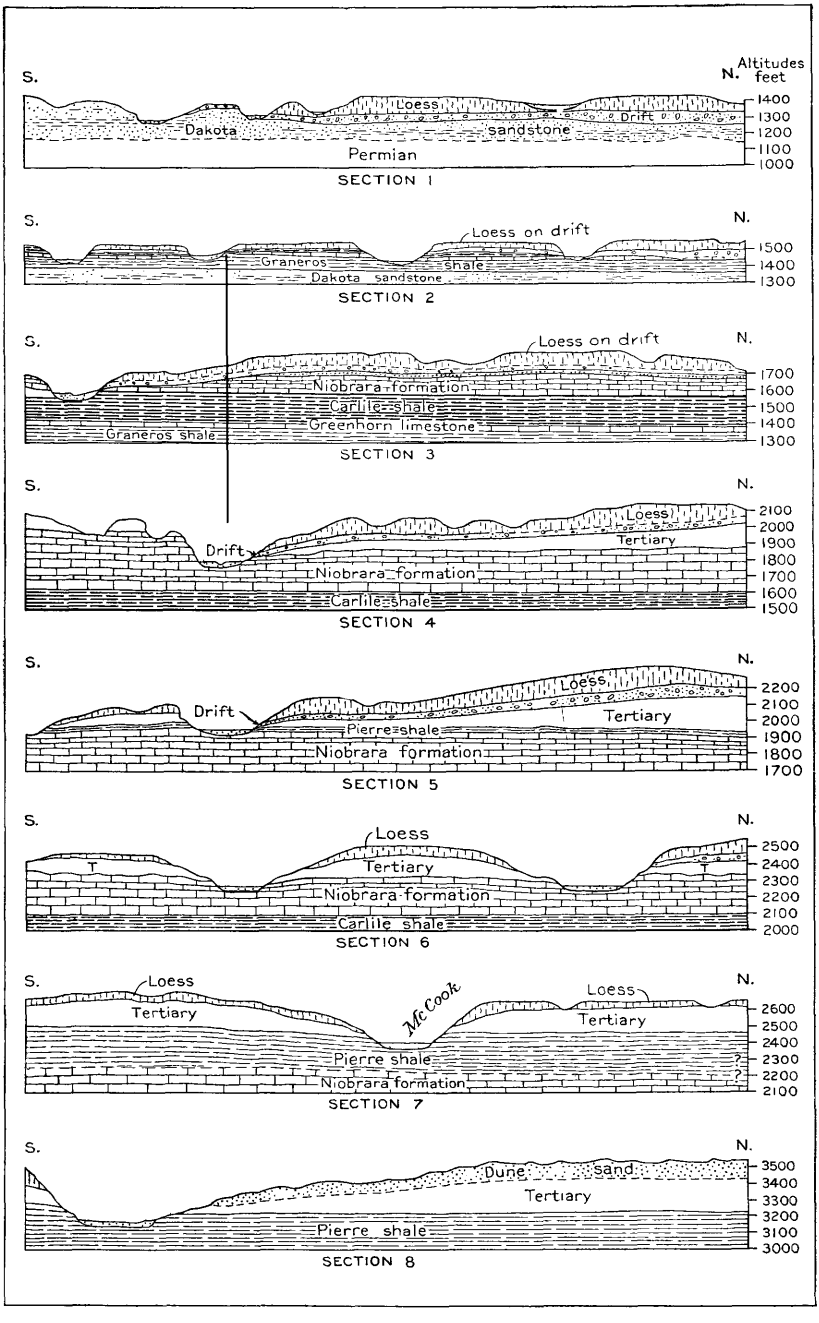
In eastern Nebraska the upper surface of the Permian rocks was a land surface in early Mesozoic time, while in the Rocky Mountain region west there was deposition of early Cretaceous, Jurassic, and Triassic sediments. Possibly some of these reach the western portion of the area treated in this report, but of this there is no evidence.

CRETACEOUS SYSTEM.

DAKOTA FORMATION.

Character and thickness.—The Dakota formation in this region consists of sandstone and clay, with the former generally predominating. While the formation as a whole shows considerable variation in stratigraphy, in most localities it is possible to recognize three members—a basal sandstone member, a medial clay member, and an upper sandstone and shale member. The lower sandstone is a medium to coarse grained variety, occurring in beds which are usually massive and cross-bedded, although in places thin bedded. Its color is gray or pale buff, but on exposed surfaces it is generally rusty brown, and portions of it are often stained to a deep brown. The clays are variegated, with red and green predominating. In some places they are more or less sandy, and thin beds of relatively pure sandstone are not infrequent. The clay is overlain by a massive, cross-bedded, dark-brown sandstone, which constitutes the upper member of the formation. This sandstone sometimes contains concretionary masses which are lighter colored and more compact than the remainder of the rock. Associated with the sandstones of the upper part of the formation are thin beds of impure lignite coal.

The Dakota formation south of Kesterson is about 275 to 300 feet thick, but the beds may thicken somewhat to the west. It is overlain



SECTIONS ACROSS SOUTHERN NEBRASKA ALONG VERTICAL LINES SHOWN ON PL. II.

conformably by the Graneros shale and unconformably by Quaternary deposits. It rests upon the eroded surface of the underlying Permian, as is indicated by the differences in altitude of the base of the formation. Many species of well-preserved fossil leaves of Upper Cretaceous age have been found in the Dakota sandstone, especially in Jefferson County. A section near Steele is as follows:

Section of Dakota formation in slopes west of Steele.

	Feet.
Sandstone, brownish, usually massive	40–60
Clay, light buff to ocher yellow	80–110
Sandstone, rusty, massive	40–55

Distribution.—The Dakota formation is extensively exposed in Jefferson County, in the eastern part of the region, where it outcrops in an area of varying width, extending across the southern townships of the county westward to a point about 6 miles west of Reynolds, where, with low westerly dip, it passes beneath the overlying formations. It is also exposed along the Little Blue River Valley from Fairbury to a point due north of Gilead, and it extends up Big Sandy Creek to Alexandria. It outcrops in the vicinity of Diller, and a small area of it is exposed along the valley of a small stream about 3 miles southeast of Plymouth. The distribution of the formation is shown on the geologic map (Pl. II, p. 10) and some of its features are shown in Pl. IV, *A*.

BENTON GROUP.

MEMBERS REPRESENTED.

It has been shown by Mr. N. H. Darton that in southern Nebraska the formation formerly called Benton consists of three distinct members, which represent the Graneros shale, Greenhorn limestone, and Carlile shale of the Rocky Mountain region. Their combined thickness here is about 270 feet to the east and 650 feet or more to the west.

Generalized section of Benton group in southern Nebraska.

Formation.	Character of materials.	Thickness.
		Feet.
Niobrara	Chalkstone	
Benton:		
Carlile	Bluish, plastic clays containing a horizon of concretions near middle; iron pyrite and selenite crystals occur throughout the clay.	75
	Dark-colored shales and clays with thin beds of fossiliferous limestone, containing large numbers of *Ostrea congesta*.	75
Greenhorn	Limestone layers, cream colored and fine grained; they contain fish remains and are interbedded with light-colored, plastic clay.	1½
	Limestone layers interbedded with clay in strata of uniform thickness, containing *Inoceramus labiatus* in great abundance.	10
Graneros	Limestone layers, fine grained, light colored, interbedded with clay; darker, more impure, and porous below.	16
	Clay and shale, mostly dark gray, containing carbonaceous and sandy beds near middle.	70
Dakota	Sandstone and sandy shales	

GRANEROS SHALE.

Character and thickness.—The Graneros shale, or lowest division of the Benton group, consists in this region of dark-colored, plastic clays and shales. Near the middle of the formation occur beds of dark carbonaceous shale which closely resemble an impure variety of coal. Just below this shale and at the base of the formation the shales are usually sandy. Large sandstone concretions abound, some of which are fossiliferous. The shales contain a large amount of iron pyrite which, by weathering, changes to melanterite, a compound which readily dissolves in water.

In its outcrop area the thickness of the Graneros varies from 40 to 70 feet, but this amount probably increases to the north and west, for the formation has a thickness of 900 feet in the Black Hills region and over 200 feet in central Colorado. It lies conformably upon Dakota sandstone and is overlain in turn by harder beds of Greenhorn limestone. It is often difficult to sharply define the lower limits of the formation, owing to the similarity between the sandy shales at the base of the Graneros and those in the upper part of the underlying Dakota. The upper limit of the formation is clearly indicated by an abrupt change in the character of the sediments.

The following section indicates the character and succession of the beds near Fairbury:

Section of Graneros shale and associated formations 5 miles northwest of Fairbury.

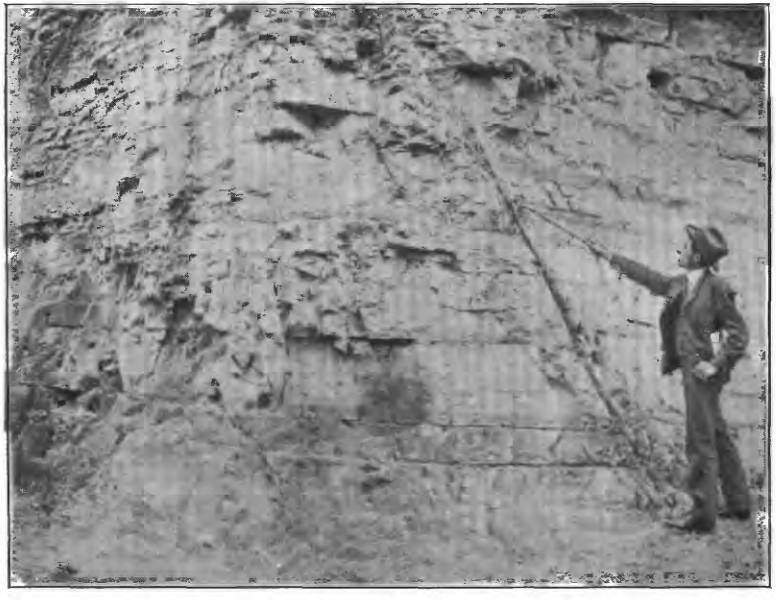
Formation.	Character of materials.	Thickness.
		Feet.
Greenhorn	Limestone alternating with beds of clay. The limestone contains *Inoceramus labiatus* in great abundance.	25
Graneros	Dark-colored shale and clay, containing thin beds of limestone	55
Dakota	Sandstone, medium grained, rust colored, with white and variegated clays below.	60

Exposures.—The Graneros shale is exposed in the eastern part of the district, mainly in Jefferson County, although exposures are found in Thayer County along Rose and Big Sandy creeks and Republican and Little Blue rivers. The most extensive exposures are in the bluffs south of Hubbell; in a small ravine on the north side of Little Blue River, southwest of Alexandria; and beneath the limestone capping slopes 4 or 5 miles northwest of Fairbury.

GREENHORN LIMESTONE.

Character and thickness.—The Greenhorn limestone, or middle formation of the Benton group, consists of limestones and clays in alternating succession. The limestones, which predominate, are soft,

A. DAKOTA SANDSTONE EAST OF ENDICOTT, NEBR.



B. NIOBRARA LIMESTONE NEAR NORTON, KANS., SHOWING SMALL FAULT.

light colored, and fine grained, and occur in beds ranging in thickness from 3 to 10 inches, the average being about 6 inches. They are usually fossiliferous, containing layers with many remains of *Inoceramus labiatus*, which is characteristic of the formation. The clays are light colored, plastic, and are in beds rarely exceeding a few inches in thickness.

The formation ranges from 25 to 30 feet thick and generally exhibits four limestone and clay members, which in regions to the south, owing to their distinctive characters, have been given local names by the Kansas geologists. The lowermost member, which in northern Kansas is a hard, dark-grayish limestone, is locally known there as the Lincoln marble. The individual beds of this member are about 8 inches thick and the total thickness is approximately 15 feet. Above the Lincoln marble there are several thin layers of white limestone interbedded with clay and having a total thickness of 10 feet, which are known as the Flagstone member. The next member consists of somewhat darker colored limestones containing many *Inocerami*, and for this reason it has been designated the *Inoceramus* member. It is 4 to 5 feet thick. The top member consists of one limestone layer about 9 inches thick, which has been called the Fencepost limestone owing to its extensive use for fence posts throughout the region.

These members of the Greenhorn formation are not so distinct in the region to which this report relates as they are in areas farther south, but they are all recognizable. In the excellent section south of Hubbell the lowermost division includes the equivalents of both the Lincoln marble and the Flagstone member, the middle division the *Inoceramus* member, and the uppermost division the Fencepost member. The *Inoceramus* member appears to be somewhat thicker in Nebraska than in Kansas. The Lincoln marble is well exposed in a cut bank along Little Blue River northwest of Gilead, where its thickness is about 15 feet.

The part of the Greenhorn limestone which is quarried appears as a light-colored streak high in the slopes in Jefferson County and in the lower parts of valleys in the eastern part of Thayer County. At a quarry 4 or 5 miles northwest of Fairbury the exposures are at an altitude of slightly less than 1,500 feet. Along the river north of Gilead the altitude of the formation is from 1,460 to 1,490 feet. Southwest of Endicott the base of the formation has an altitude of about 1,525 feet. The beds quarried south of Kesterson have an altitude of 1,535 feet, while at Hubbell they are at about 1,505 or 1,510 feet. Westward along Rose Creek Valley the beds gradually sink from high in the slope and reach the level of the valley bottom between Hubbell and Chester. These facts indicate that the formation dips gently to the northwest except for a

small local flexure in the southern part of Jefferson County. Where present at the surface the limestones form a ridge or escarpment in the valley slopes, below which the underlying Graneros shale is marked by a clay slope.

Fossils.—*Inoceramus labiatus*, which characterizes this formation, occurs in large numbers in most of the beds. The formation has also yielded several specimens of fossil fish, and Dr. G. A. Birdsall, of Alexandria, has collected vertebræ and bones of various kinds from quarries north of Gilead. Mr. C. A. Carmony obtained, south of Kesterson, a large ammonite, which is now on exhibition in the State Museum of the University of Nebraska. The best specimens of fish remains are found in the fine-grained limestone layers near the top of the formation.

CARLILE SHALE.

Character and thickness.—The Carlile shale, the uppermost formation of the Benton group, consists of dark-colored clays and shales, which, in Kansas, have been separated into two members. The lower, which is the more calcareous, carrying thin beds of fossiliferous limestones, has in that State been designated the *Ostrea* horizon, on account of the presence of large numbers of *Ostrea congesta*, while the upper, which is composed of bluish, plastic clays, with fewer fossils, has there been designated the "*Septarian* zone" or Blue Hill beds. Near the middle of this upper member is a horizon of biscuit-shaped concretions, which is well exposed in the vicinity of Lovewell, Kans. These concretions are often traversed by cracks filled with calcite, selenite, and occasional crystals of barite. They are generally large, some exceeding 6 feet in diameter. Throughout the formation and especially in its upper part there are large quantities of iron pyrite, which decomposes to sulphate of iron, or melanterite, a mineral which appears on the surface as a light-colored powder of acrid taste. By chemical reaction the decomposing pyrite in the clay banks also forms calcium sulphate, which crystallizes as selenite, and crystals of this mineral are usually scattered over the surface in great abundance.

The exact thickness of the formation is believed to be over 200 feet in Nuckolls County and westward, but owing to erosion of its upper surface it thins out in Jefferson County along an eastern margin shown on the map (Pl. II).

Exposures.—The Carlile shale is not extensively exposed in the area included in this report, but it outcrops at intervals along the valleys of Republican and Little Blue rivers and Rose Creek. It usually appears on the slopes as a narrow band overlain by loess and resting upon greenhorn limestone. Along the south margin of the district

it is exposed as an area of irregular width capping the higher land from a point nearly due south of Kesterson to near where Republican River crosses the State line.

NIOBRARA FORMATION.

Character and thickness.—The Niobrara formation in southern Nebraska consists principally of a chalky limestone known as chalk rock, with interbedded layers of calcareous clay and local deposits of flint. The prevailing colors of the rock are lead gray, light gray, and yellowish, depending on the degree of weathering. Much of the weathered rock is straw yellow, and in certain localities is ocherous in color; in the bluffs south of Guide Rock, where the weathered portions of the rock are rapidly removed by erosion, it is lead gray with a decided bluish tint. The chalk rock has a porous texture and gives a hollow sound when struck with a hammer. It has an uneven fracture and a tendency to break into splinter-like forms. It varies considerably in composition from place to place, the principal impurities being clay, silica, and gypsum. Where clay is present in large amounts the beds are usually shaly.

In previous descriptions of the geology of this portion of Nebraska, no subdivisions were made of the Niobrara formation, which was described as consisting mainly of soft limestone chalk rock, or limy clays, presenting considerable variation from place to place. It has been found, however, that it comprises two distinct members, a lower and an upper, which are probably equivalent, respectively, to the Fort Hays beds and the Smoky Hill chalk of Kansas. The total thickness is about 400 feet. Some features of the formation are shown in Pls. IV, *B*, and VIII, *A*.

The basal member of the Niobrara consists of massive soft chalky limestones, bluish to light gray on freshly broken surfaces, but weathering to yellowish. The thickness of this member varies from 40 to 50 feet and the outcrops are usually marked by more or less prominent ledges capping the softer shales of the underlying Carlile formation. Extensive exposures of these beds occur on the south side of Republican River between Superior and Bostwick, and along Whiterock Creek in Kansas.

In southern Nebraska the upper member of the Niobrara formation is about 300 feet thick. It consists of a bluish-gray chalk, generally massive and irregularly jointed, with layers of light-colored limestone and calcareous clays distributed throughout. The beds in the upper part vary considerably in character in different localities. Wherever the formation is overlain by Pierre shale the chalky beds continue to the top of the formation, but in a wide area in the vicinity of Cambridge, and in the southern part of Nuckolls County, where

the Pierre is absent, the upper beds of the Niobrara are ocherous and more or less flinty. The flint is brownish, reddish, or greenish in color; it occurs in continuous beds in the top of the formation, but lower down in scattered nodules; the beds vary in thickness from a few inches to 10 feet, and it is believed that they have accumulated in the chalk subsequent to its deposition, probably during late Tertiary or Quaternary times.

Fossils.—Fossils are very abundant in the Niobrara formation. *Ostrea congesta* and a large flat *Inoceramus* are the most common forms, the former often attached to fragments of the latter. Well-preserved fish remains are not infrequent, and turtles have been collected in the vicinity of Cambridge. The chalk rock, when examined closely, is found to be composed largely of minute shells which grade in size from those plainly visible to the unaided eye to microscopic forms.

Distribution.—The Niobrara formation has a relatively wide outcrop area in central-southern Nebraska. It first appears under the loess in isolated areas in the valley of Little Blue River and its tributaries above Angus, at Nelson in the central part of Nuckolls County, and farther south on either side of Smyrna and near Bostwick. The formation outcrops most extensively along Republican River and its tributaries, rising high on the slopes south of Guide Rock. Westward it gradually falls to lower levels on the slopes, until, in the vicinity of Republican, its exposures are principally limited to the lowlands of the valley. At Edison the Niobrara outcrops narrow somewhat, and the Pierre shale occupies a portion of the bottom lands on either side, but to the west it widens again, retaining a nearly uniform width to the point where it passes beneath the Pierre shale south of Indianola. In the low valley land along Republican River the Niobrara formation is generally covered by Quaternary deposits. At Riverton, Republican, and south of Orleans the alluvial deposits have been removed, exposing the chalk rock in the banks of the river. The Niobrara occupies the lowlands of Beaver Creek Valley from its mouth westward to near Danbury, and along Sappa Creek, its main tributary, to beyond the Nebraska-Kansas State line, but it is nearly always covered by a thin deposit of alluvium. The eastern margin of the formation under the loess is near the east line of Nuckolls County. The details of the distribution of this formation are shown on the geologic map, Pl. II.

PIERRE SHALE.

Character and thickness.—The Pierre shale, as exposed along the Republican Valley in southern Nebraska, consists mainly of plastic, loose-textured, carbonaceous clays which become shaly on weathered

surfaces. The clays are unctuous when moist and hence are popularly known as soapstone. The common colors are dark bluish to black, with many rust-colored spots. Gypsum crystals are distributed throughout the shales, weathering out in great abundance on the barren slopes, and iron pyrites are found in thin layers at many horizons. The pyrite decomposes readily, and much of the resulting product is scattered over the surface as irregular fragments of iron oxide. The maximum thickness which the formation reaches in the western part of Dundy County is not known, but apparently it is more than 1,000 feet. No reliable well records could be obtained to show the thickness underground, but the formation is known to thicken rapidly to the west and north, reaching 7,700 feet west of Denver. In the syncline between Arapahoe and Naponee it has a thickness of 50 feet or more and thins out to the east and the west. A well-defined layer in the Pierre shale in this region consists of a carbonaceous shale resembling an impure coal in some respects. This layer has a thickness of about 25 feet, and is well exhibited along the Republican from near the Alma bridge to beyond Orleans. The shales of this member are least plastic near the top and erosion often develops buttresses and recesses in them. The bedding and jointing are fairly distinct, and many layers and joint seams contain gypsum as a yellowish powder. Overlying this carbonaceous member are dark-bluish clays, with well-defined bedding, but fewer joints. In Dundy County the upper part of the exposed Pierre for 10 to 12 feet are of yellowish color. The Pierre shale contains a few fossils, such as *Baculites compressus* and small ammonites.

Distribution.—The Pierre shale rests conformably on the Niobrara and is overlain unconformably by Tertiary deposits (see Pl. V, *B*). It is exposed along the Republican and its tributaries from the western part of Franklin County to the vicinity of Arapahoe, and from near Indianola to the west line of the State. It also extends for some distance up Prairiedog Creek to beyond the Nebraska-Kansas line, and up Sappa and Beaver creeks into the eastern margin of Furnas County. It reappears in the valley of Sappa Creek a short distance above Lebanon and continues to beyond the State line.

TERTIARY SYSTEM.

The Tertiary deposits of southwestern Nebraska appear to belong entirely to the later epoch of that system but they have not as yet been definitely classified. Apparently the principal formation corresponds to the Ogalalla of Darton, but possibly to some of the Arikaree as well.

Character and thickness.—The Tertiary deposits consist mainly of sand, gravel, and clay, in places bound together by calcareous cement

into beds of variable hardness. Their character varies greatly from place to place. The sands are mostly medium to fine grained, often grading into a coarse cross-bedded sand and gravel. The gravel is waterworn and varies in size from small pebbles to bowlders 4 to 6 inches in diameter. (See Pls. V, *C*, and VI, *B*.) The materials comprise quartz, feldspar, granite, andesite, and porphyry, apparently derived from the Rocky Mountins. The clays are usually sandy, sometimes becoming so fine grained as to be a silt or loam. Deposits of this character occur north of Max, where there is much clay or loess-like silt, but in general the greater part of the sediment consists of sand and gravel irregularly mixed and often imperfectly stratified. Volcanic ash is generally associated with the sand beds and it occurs in lens-shaped deposits or beds in a number of places. The usual color of the ash is light gray and it is medium to fine grained. Opalized wood is scattered over the surface at various places in the Tertiary outcrop, notable localities being southeast of Laird and at the head of Rock Creek. At a few places in the western counties the calcareous cement occurs in sufficient amount for use as a natural plaster. A partial section of the Tertiary beds, as exhibited southeast of Franklin (see Pl. V, *A*), is given below:

Section at Lookout Mountain southeast of Franklin, Nebr.

	Feet.
Limy sand rock, texture varying; color gray to white	10
Sand, light colored on surface, fine grained, at places lithified	10
Quartzite, light to olive-green color; texture variable, but usually medium grained; siliceous cement	1½
Sand of various colors and medium grained	30
Chalk rock (Niobrara); colors, yellowish at top, whitish and bluish gray below	200
	251½

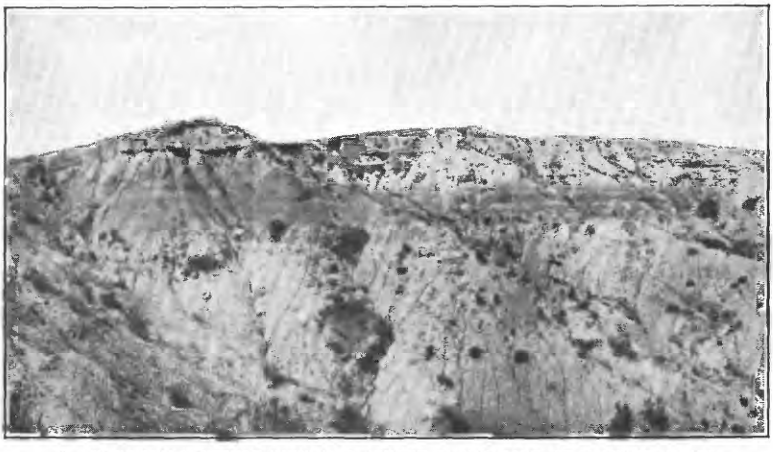
Distribution.—The Tertiary deposits are exposed along the south side of Republican Valley from a point south of Red Cloud to Edison, and thence westward to the Nebraska-Colorado line along both sides of the valleys of the Republican and its principal tributaries. They are also exposed along Beaver and Sappa creeks and their numerous small branches throughout their entire extent within the area. The formation lies on the uneven surface of the Pierre (see Pl. V, *B*) and Niobrara formations, and is in turn extensively overlain by loess and other Quaternary deposits.

QUATERNARY SYSTEM.

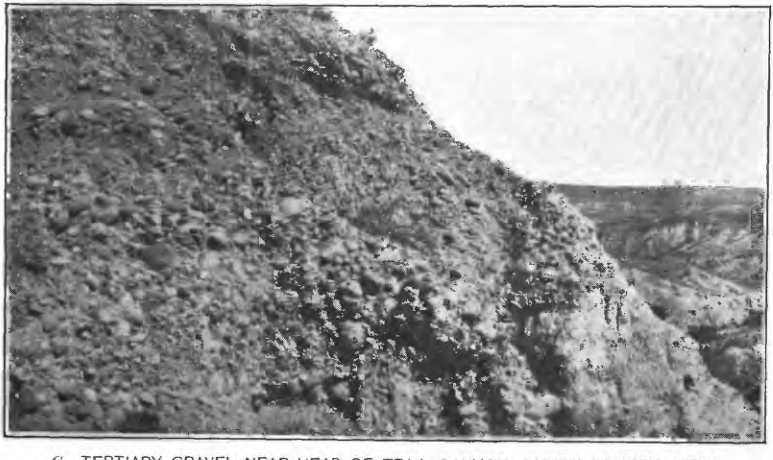
DRIFT.

The greater part of Nebraska is covered by a thin but widespread sheet of sands and gravels, transported to the region by glaciers from the north and by streams from the west during Pleistocene

A. LOOKOUT MOUNTAIN, SOUTHEAST OF FRANKLIN, NEBR., SHOWING BLUFFS CAPPED BY TERTIARY SANDY LIME ROCK.



B. TERTIARY "MORTAR BEDS" ON PIERRE SHALE EAST OF HAIGLER, NEBR.



C. TERTIARY GRAVEL NEAR HEAD OF TRAIL CANYON, DUNDY COUNTY, NEBR.

time. The glacial deposits have been called northern or glacial drift, and the stream deposits western drift. The glacial drift occurs only in the eastern part of the region treated in this report—that is, in Jefferson County and the eastern part of Thayer County—but it extends north across eastern Nebraska. The greater part of the material is till with scattered deposits of bowlders, and it is more or less overlain by loess, especially to the west, where its margin is hidden by the loess. The sands and gravels of western origin extend westward under the loess, and in Jefferson County, especially along the Little Blue, appear to merge into the glacial drift, but the contact relations are not clearly exposed.

The glacial drift in Jefferson and Thayer counties lies unconformably on the Dakota, Graneros, Greenhorn, and Carlile formations, and in places, especially on the uplands, is covered by loess. The glacial sands and gravels at Fairbury appear to be older than much of the clayey till in eastern Nebraska. They are separable at places into two members, an upper rusty-colored one and an underlying lighter colored and locally more regularly stratified member. These two show best in the sandpit of the Rock Island Railroad, about 4 or 5 miles northwest of Fairbury. Bowlders and pebbles occur in both divisions, but they are more noticeable in the upper one, perhaps because this is the more exposed and eroded.

A thin bed of brownish to yellowish clay till caps the glacial sands in the uplands about Fairbury, coming as low as 1,370 feet in altitude, but usually not much below the 1,380-foot level. It increases in thickness eastward in the direction of Jansen, Plymouth, and Lincoln. This clay contains pebbles and bowlders, usually of pinkish quartzite. It rises to an altitude of 1,430 feet 1 mile northeast of Jansen and to about 1,400 feet in the vicinity of the Chicago and Rock Island Railroad bridge across Cub Creek, at which place about 40 feet are exposed. In a railroad cut just west of this bridge the till is separable into two divisions. The lower, 12 feet of which rise above the level of the track, is sandy and concretionary, with few pebbles and bowlders; of the upper, about 11 feet of typical yellowish, pebbly, and bowldery clay are exposed in the cut, and it rises still higher in the hill slope. This member of the drift is distinct from the loess, by which it is covered to a depth of 30 to 45 feet at Plymouth.

Concretions often occurring in the till are composed of calcium carbonate. They range from 1 inch to more than 4 inches in diameter.

In general, there are two fairly distinct members of the glacial drift in Jefferson County, as shown by a section between Fairbury and Plymouth, both containing bowlders and both showing smaller local divisions. Small deposits of clay have been observed to occur in

the sand and gravel. Clay which may prove to be of glacial origin is found along the Chicago and Rock Island Railroad southwest of Thompson, and even as far west as Nelson.

The vertical range of glacial bowlders and till is from altitudes of 1,250 to over 1,500 feet. The exposed bowlders are confined to Jefferson County, with a few in Thayer County. They occur for the most part east of Little Blue River, but extend 2 to 4 miles west of that river, between Powell and Steele, and to only a few miles south of Rose Creek. They come to the surface where the loess and finer parts of the till are eroded, and in some places they become abundant. The largest area of this kind is located just southeast of Endicott, where bowlders, mostly of Sioux quartzite, with a relatively small number of granite, cover nearly 2 square miles of the Dakota escarpment and adjoining slopes (see Pl. VI, *B*). These bowlders have been concentrated from till by the removal of the sand and loam by erosion. In the greater part of Jefferson County east of the river bowlders usually occur beneath the loess cap, and where the loess has been eroded the bowlders and other coarser glacial materials are brought to view. Other bowlder areas occur near Steele, Fairbury, and at a number of places in Cub Creek Valley. A large quartzite bowlder northeast of Fairbury, $4\frac{1}{2}$ by 9 by 10 feet in size, is shown in Pl. VI, *A*. Another of coarse-grained granite, $4\frac{1}{2}$ by $6\frac{3}{4}$ by 17 feet in size, is located in a gravel bench one-half mile away; its size has been reduced by blasting. The glacial bowlders comprise Sioux quartzite, granites, syenites, gneiss, hornblendic and mica schists, flinty limestone, Dakota sandstone, and Greenhorn limestone. Some of these were carried long distances by ice, while others came from ledges not distant. The granitoid rocks are rounded in part by weathering, but most of the quartzites are angular and little worn.

It appears that the presence of the ice sheet in Jefferson County affected the drainage over wide areas westward, causing the rivers to fill up their valleys and then to spread sediment over the general region along and to the west of the glaciers. The deposits of western drift are found as far west as Arapahoe, Cambridge, and Trenton. That this deposit is of western origin is proved by the presence of a large amount of typical Rocky Mountain rock. Much of it, however, came from Tertiary formations which were derived from the Rocky Mountain region.

Remains of the primitive elephant have been found in the Fairbury gravels.

All of the glacial drift in the region treated in this report is generally known as the Kansan drift. A part of it may be of Aftonian age.

A. QUARTZITE BOWLDER NORTHEAST OF FAIRBURY, NEBR.

B. GLACIAL BOWLDERS SOUTHEAST OF ENDICOTT, NEBR.

LOESS.

This formation constitutes the surface of the greater part of southeastern Nebraska and adjoining regions. Originally it covered the entire surface, but it has been cut through by the larger streams and now remains on the wide plateau areas between the valleys. The typical loess is characterized by its fine, even-grained, massive structure, porous texture, light-buff color, and the presence of a weak calcareous cement. It is often called the "bluff" deposit where deep canyons and river bluffs are formed of it, because, owing to its massive structure, it weathers into steep slopes. The well drillers speak of it as "yellow clay." The loess generally lies directly upon glacial drift or the western gravel deposits, but also overlaps on the older formations. Its thickness on the high loess plains is about 100 feet. The formation has a strong tendency to vertical displacement in canyon walls and bluffs, so that on many slopes it settles or creeps over the edges of the underlying formations, concealing them from view. Where eroded by running water it stands in nearly vertical banks. On account of its massive structure and coherent nature, many wells bored in the loess region do not require casing in the part penetrating this formation. Ordinarily cellars in loess do not require to be walled.

The loess varies noticeably in color and somewhat in texture in different parts of the region, varying from light buff to brownish, a difference apparently related to the underlying beds, for the color is lightest where the loess overlies the light-colored Niobrara chalk rock and darkest when on or near the ocherous Niobrara and the Dakota formation.

The loess consists principally of silt and clay particles loosely cemented by carbonate of lime and stained by a small amount of iron oxide. The proportion of each of these ingredients varies from place to place. The silt grains increase in size and proportionate amount from east to west and apparently also with depth. The upper surface of the loess is darkened by humus and grades into the cultivable soil.

The mode of accumulation of the loess has been a subject of much discussion. According to the earlier view it is a wind-blown deposit, while according to a later view it was deposited over a wide extent of country by low-grade streams at the close of the Pleistocene; probably both of these agencies have been factors in its origin.

It contains numerous fossil shells, mostly gasteropods, of freshwater nature.

TERRACE DEPOSITS.

Terraces are conspicuous along Republican River and Beaver, Sappa, and Prairiedog creeks. They are locally known as benches,

or as second and third bottom lands. Their heights in the Republican Valley are mostly 6 to 14, 25 to 40, and from 60 to 80 feet above the first bottom. Low benches are clearly defined in the vicinity of Haigler. At Oxford they are from 6 to 8 feet high. The terrace extending along the south side of Republican River from Amboy to a point southwest of Superior is 25 to 30 feet high. Four miles west of Benkelman a high terrace rises about 75 feet above the river. At several places in Dundy County and in the western part of Hitchcock County the wind has eroded the terraces into dune-sand topography, as illustrated in Pl. VII, *B*. Terraces on the south side of Republican River are less continuous than those on the north, owing mainly to the fact that the river crowds the right bank at places and has entirely removed the benches.

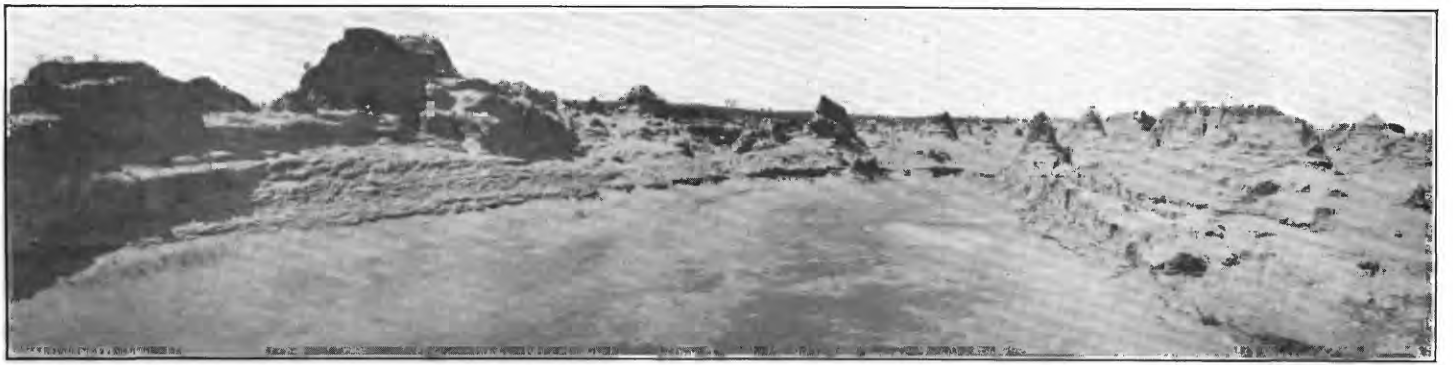
The terraces are capped by an alluvial deposit resembling somewhat the loess in texture, but showing more definite stratification and greater variation in the size of the component parts. The material in the high terraces in Dundy and Hitchcock contains a large amount of silt and in many respects resembles the loess to the west. It contains remains of the primitive elephant and the mastodon. Bones of *Elephas primigenius* were found by Mr. Max in the terrace deposits just north of the town of Max; other remains of this species have also been collected from these beds along Driftwood Creek 12 miles south of Trenton and at several other localities in the region.

ALLUVIUM.

A relatively thick deposit of alluvium occupies the floors of all the principal valleys and their tributaries throughout this portion of Nebraska. It generally consists of sand, gravel, and clay which shows considerable variation in character in different parts of the region.

The thickness of the deposit varies from 20 to 80 feet, the average being about 50 feet. The broader areas of alluvium are composed of fine sand near the surface, with medium to coarse gravel below, and in most localities beds of clay of variable thickness have been encountered by well drillers. Along the smaller tributaries the alluvium varies greatly in amount and character, according to the nature of the formations from which the material is supplied. The smaller streams traversing Tertiary, Dakota, or Pleistocene formations usually contain much alluvial sand and gravel, while those flowing over only Niobrara and Benton formations have but little alluvium along their course, for the materials, being fine-grained, are usually transported at flood times to the larger stream courses, leaving the bed rock uncovered. At Fairbury, along Little Blue River, the alluvial bottom land is from ½ to 2 miles in width. The depth of the deposit is not definitely known, but it has been penetrated to reported depths

A. TERRACES NEAR MOUTH OF TRAIL CREEK, DUNDY COUNTY, NEBR.



B. WIND EROSION IN HIGH TERRACE WEST OF BENKELMAN, NEBR.

of 60 to 80 feet. In this region it is composed of medium to coarse sand, gravel, and clay, with a small proportion of decomposed organic matter.

DUNE SANDS.

In the western part of Dundy County, northeast of Haigler, the Tertiary sands have been blown by winds into hills and ridges, with intervening dry valleys and basins forming a typical sand-hill region, as shown in Pl. VIII, *B*. In some places along the Republican, as far east as Trenton, the high, silty terrace has been more or less eroded by the wind, forming blow-outs and dunes. In places the dune sands are encroaching on the river. The veneer of sand is thin, and has been largely derived from the Tertiary materials and high-terrace deposits. Small terrace dunes are also found along the sandy bottoms of Little Blue River near Fairbury and at numerous places along the Republican.

ECONOMIC GEOLOGY.

MINERAL RESOURCES

The region to which this report relates possesses various mineral resources, some of which are sufficiently valuable to warrant development.

COAL.

Prospecting for coal has been in progress throughout the region since the time of earliest settlement. Three carbonaceous horizons, each in a different formation, have seemed promising to prospectors.

The first is in the upper part of the Dakota formation, where thin beds of impure lignite occur. During 1903 a small amount of this coal was mined three-quarters mile east of Powell, Jefferson County. The thickest bed at this place is about 7 inches and it outcrops in a ravine north of Little Blue River. Thin beds of lignite probably occur in many parts of the Dakota formation throughout the region, but there are few outcrops, and it is doubtful if the material ever reaches a workable thickness. Coal is mined to some extent from the Dakota formation at a few localities in Kansas, south of Thayer and Nuckolls counties, and the same amount and quality of coal that is worked in Jewel County, Kans., is believed to extend to the vicinity of Hardy and Superior, Nebr., but the depth at which it would be reached then entirely precludes the possibility of working it successfully.

The second carbonaceous horizon lies above the Dakota in the Graneros shale, the lowest division of the Benton group. The rock of this horizon outcrops at several places in Jefferson County, where it has been prospected extensively, but without success.

The third carbonaceous horizon referred to is in the lower part of the Pierre shale. It has been prospected more or less in the region between Republican and Arapahoe, also south and west of Orleans, but offers no encouragement whatever of affording true coal or lignite.

PETROLEUM AND NATURAL GAS.

While there are no grounds for believing that petroleum and gas may be obtained by borings in the Republican Valley region, these materials may possibly occur, and the possibilities are such as to warrant more complete and detailed investigation. There are no surface indications of oil and the only gas reported is a small amount in a well 405 feet deep at McCook. This well yields a flow sufficient to afford a flame that flashes up from a cap on the casing and burns more strongly than an ordinary gas jet. The engineer at the pumping station where the well is located stated that enough gas collects in the cap to burn about one-half hour.

The presence, discovered by Mr. Darton several years ago, of an anticlinal arch in Furnas County, has excited much interest in its relation to the possible occurrence of oil or gas, and plans have been made for drilling for these products. The crest of this arch extends down Medicine Creek through Cambridge and southeastward across Furnas County, and if oil or gas are present underground they might be expected along that line. There is, however, no evidence whatever that the region is underlain by rocks containing oil or gas. The Dakota sandstone, which lies about 700 feet below the river at Cambridge has never yielded oil, and probably at a depth of about 1,000 feet it is underlain by red beds, which are nonproductive; the thickness of the latter is unknown, but probably it is over 500 feet. The red beds are underlain by limestone and shale, which might possibly yield some products of value; the depth of these increases rapidly to the west and to the east of the arch.

The Carboniferous rocks which carry oil and gas in southeastern Kansas extend under south-central Nebraska, but several deep wells which have penetrated these rocks in northern Kansas found no oil. The Dakota formation under the Republican Valley carries artesian water under heavy pressure, a condition which would prevent the accumulation of oil or gas. The oil of eastern Colorado is obtained from sandy beds in the Pierre shale, and possibly such beds may be found in the formation in Hitchcock and Dundy counties.

BUILDING STONE.

Building stone is quarried at many points in the Republican Valley. The Dakota sandstone, though more or less friable and not of pleas-

A. NIOBRARA LIMESTONE QUARRY NORTHEAST OF CAMBRIDGE, NEBR.

B. TYPICAL SAND HILLS NORTHEAST OF HAIGLER, NEBR.

ing color, is quarried southeast of Endicott and southeast of Kesterson. This material is used mainly for foundations and culverts in Fairbury, Endicott, and Steele. A thin bed of compact sandstone is found in the Dakota formation about 2 miles northwest of Fairbury, which closely resembles quartzite, and a hard sandstone similar in character occurs near Junction, but neither of these is sufficiently extensive to be valuable. The Greenhorn limestone has been quarried for twenty years in the vicinity of Hubbell, and although the present output is only about 40 cars per year it formerly exceeded 200 cars. Most of this stone is now used in the northern part of Kansas. A line of small quarries extends along the hill slopes wherever the Greenhorn formation is exposed. The principal quarries of this rock within this region are located about 5 miles northwest of Fairbury, a few miles northeast of Gladstone, north of Gilead, south of Kesterson, and in the vicinity of Hubbell. Most of the stone is obtained from the so-called Fencepost member, and other beds are worked locally. The product is used principally in building foundations, culverts, and sidewalks. The Greenhorn limestone is used for structural purposes throughout Jefferson, Thayer, and Nuckolls counties. It has been burned successfully to lime northwest of Fairbury.

The Niobrara chalk rock, though soft, has been quarried for building purposes along the Republican, between Superior and Alma. It is easily dressed and its color is not objectionable. The lower member of the formation has been less extensively quarried in Nebraska than in Kansas, where it is crushed at Montrose and used for ballast along the Chicago, Rock Island, and Pacific Railway. At Alma the upper beds of the Niobrara have been used for street pavements. The chalk packs firmly, sheds water, and wears well. In the vicinity of Cambridge, flinty beds of the Niobrara are quarried for building purposes. The A. Brown quarry (Pl. VIII, *A*), 2½ miles northeast of Cambridge, has been worked for twenty years. This flint extends over a wide area in the vicinity of the anticline both in Nebraska and in Kansas, and it might be used as a railroad ballast.

The Tertiary "mortar beds" afford stone suitable for foundation purposes in every county west of Harlan. The so-called "granite" at Woodruff is a compact sandstone, or quartzite occurring in the Tertiary. It is quarried and crushed for railroad ballast and concrete at the Atwood Company's quarry, about 2 miles west of Woodruff, Kans., and about one-fourth mile south of the State line. The stone is very hard, usually olive green in color and fine to medium grained, but the color and texture show some variation. The beds quarried range from 6 to 12 feet in thickness. Stone of this horizon occurs in the vicinity of Lookout Mountain southeast of Franklin, Nebr., where large blocks appear on the slopes of the hill. A ledge of

rock of somewhat similar nature but of finer texture outcrops at places along Republican River in Furnas and Redwillow counties. It is 3 to 4 feet thick, and best exposed south of the river between Bartlett and Indianola.

CEMENT.

Portland cement is largely manufactured from limestone or chalk mixed with the proper proportion of clay or shale. These materials are ground, thoroughly mixed together and burned, and then reground. The Niobrara chalk rock and the Pierre shale are used in the manufacture of cement at Yankton, S. Dak., and these same formations outcrop along the Republican, where probably they could be utilized for that purpose. Unfortunately, in the area in which the chalk rock is most favorably exposed, it is not overlain by the clay, but large supplies of this ingredient could be obtained at no great distance. Other important factors to be considered in the production of cement, aside from the materials used, are fuel and water supply, but the conditions for these are as favorable in Republican Valley as in some other places where cement is profitably produced.

CLAY.

The Dakota formation contains extensive beds of high-class clays near Fairbury, Endicott, and Steele. Southeast of Steele the middle member of the formation is composed of light-colored to mottled clays, which appear over an area of several square miles, in slopes rising from the level of the river to an altitude of 1,325 feet. Between Steele and Endicott there is a clay pit from which the product is shipped to Hastings and Beatrice for use in the manufacture of brick and tiling. An abandoned pit near Endicott, which was worked out by a Beatrice firm a few years ago, afforded over 1,000 cars of clay for use in the manufacture of brick, pottery, and tiling. Clays of the Dakota formation produce very fine grades of brick and on that account will doubtless be more extensively used. Unfortunately there are no large towns near the outcrop areas, and the haulage to Lincoln and other principal cities of Nebraska is long and expensive. There are brickyards in most counties of the region manufacturing brick from either Dakota clay, loess, or alluvium. The principal yards are at Fairbury, Hebron, Deshler, Nelson, Alma, Beaver City, and Arapahoe.

SAND AND GRAVEL.

Some of the deposits of sand and gravel in the Republican Valley will eventually prove to be valuable. The sand is extensively distributed while the gravel is of less common occurrence. Most sandpits are operated for local use, yet a few ship to towns some distance away.

The sands and gravels worked come from the Dakota formation and from Tertiary, glacial, and alluvial deposits, the last two being the most important sources. The Dakota formation contains friable sandstone, which at places afford a small supply of sand. The Tertiary sands are mostly fine grained, but the gravels are locally coarse enough for use as railroad ballast. It is from the stratified deposits formed during the Pleistocene that most of the sand and gravel is obtained. The principal materials are of western origin and outcrop along Little Blue and Republican rivers. Along the former they are intermixed somewhat with materials of glacial origin and are coarser than the deposits farther west. The main center for sand and gravel is Fairbury, but the deposits extend far westward and are worked at or near Superior, Red Cloud, Beaver, Arapahoe, Cambridge, Trenton, and beyond. The sands usually lie in an accessible position just below the loess. There is an inexhaustible supply of coarse sand and fine gravel about Kesterson, Fairbury Junction, Helvey, Powell, and Hebron. The lower surface in Jefferson County is very irregular, resting on the eroded upper surface of older formations. In places the sand is not overlain by loess and at such places very little or no stripping is necessary. Where railroad facilities are favorable the expense of production is low.

The other principal source of sand is the alluvial deposits. The sand in the Republican bottom lands averages too fine for plaster, but might be used as a filler for concrete work and it may yet prove to be adapted to the production of sand-lime brick. Where the deposits along the streams have been derived from near-by glacial sands they have not changed greatly in character, but remain coarse enough for building purposes. This is the case in the deeper parts of the flood plain from Alexandria to Fairbury. The sands along the river at Fairbury are reported more than 80 feet thick at places. In the vicinity of Bostwick a small ravine contains much coarse sand derived from a bed beneath the loess and this sand is used locally for plaster. In many localities there are sand deposits under the loess, but they are not often well exposed.

Sandpits are found in the vicinity of nearly all towns. The largest shipments are from the Chicago, Rock Island and Pacific Railway sandpit, located northwest of Fairbury on a switch of the Nelson Branch. An old pit on a switch of the Chicago, Burlington and Quincy Railroad just west of Kesterson has afforded thousands of tons during the many years in which it has been worked. The St. Joseph and Grand Island Railway ships from a pit about midway between Endicott and Steele.

The sand of the various pits is used principally for plaster, masonry construction, ballast, and in the manufacture of artificial stone. The demand for it is increasing for each purpose named, especially

the last. Artificial stone plants are operating now in most of the larger towns where a supply of sand can be had within a few miles, as at Fairbury, Hebron, Superior, Nelson, Red Cloud, Cambridge, and McCook. The product is becoming not only a rival of natural stone but of brick as well.

VOLCANIC ASH.

Volcanic ash is a light-colored powdery deposit of volcanic origin. It is thought to have been thrown into the air by volcanoes in the mountains and carried far eastward by the wind, and in some cases to have been again taken up later and redeposited by water. It is composed of hard, angular fragments of volcanic glass resembling pulverized pumice, and occurs as thin beds and irregular pockets in the Tertiary formations. The thickest beds are in Furnas and Harlan counties.

Mr. S. C. Zike formerly hauled and shipped from a pit 5 miles south of Edison from an opening now 30 feet high and over 100 feet long. The ash was shipped to some of the larger eastern cities. Mr. J. C. Gay of Orleans is shipping the ash from that town under the name of silica. The product goes principally to Europe and is used as an abrasive and in the manufacture of sapolio.

The following analysis of Harlan County ash by Mr. R. S. Hiltner gives the chemical composition:

Analysis of volcanic ash from Harlan County.

	Per cent.
Silica (SiO_2)	71.56
Iron oxide and alumina (Fe_2O_3 and Al_2O_3)	15.04
Calcium oxide (CaO)	1.19
Magnesium oxide (MgO)	.49
Sodium and potassium oxides (Na_2O and K_2O)	5.51
Sulphuric anhydride (SO_3)	.73
Loss on ignition	5.48
	100

OCHER.

Two formations carry ocher (hydrated oxide of iron), which is used to a limited extent for paints. The Dakota clays east of Endicott, and in secs. 19, 24, and 30, T. 1, R. 3 E., southeast of Kesterson, contain a large admixture of reddish and yellowish ocher. In the last-named locality the yellowish to reddish deposits extend onto a number of slopes in that vicinity.

Portions of the Niobrara formation are ocherous in much of Franklin and Webster counties, and also on the anticlinal fold farther west, where the Pierre clay has been removed by erosion. At Indianola paints are manufactured from the weathered upper surface of

the Niobrara at a level of 30 feet below the town. The bed is 11 feet thick at a shaft in the western part of the town, and thins out southward. The ocher was mined about twelve years ago; the shaft has been reopened recently by Adolph Smith and J. P. Reiter, who have installed a mill and are now placing several grades of the product on the market.

WATER RESOURCES.

On account of their economic importance and their close relation to public health the water resources, especially the underground water of this region have been given special consideration. The principal water supplies are obtained from wells, springs, streams, and lakes or ponds. These may be classified as surface and underground waters.

SURFACE WATERS.

GENERAL CHARACTER.

The surface waters in this region are products of local rainfall in a catchment area but very slightly larger than the district to which this report relates. The amount of direct run-off in any region depends on the quantity and nature of the rainfall, the texture of the soil, and the drainage conditions, the maximum amount being where steep slopes prevail and the soil is fine textured. The run-off in this district is largest in the rougher parts of the central counties and eastward, where the rainfall is greater and the fine-grained loess soil covers most of the surface, the minimum amount being lost where the soil is open textured and the land not surface drained. In the sand-hill region and in most of the Tertiary area the direct run-off is small and much water is absorbed; the rainfall is light and the soil is very porous.

In certain canyons heading high in the table-lands the run-off is large, especially after a hard, driving rain. Train Canyon, for example, has bare clay slopes, great declivity, no springs, and never carries water except after what is called a waterspout. At such times water fills the canyon and flows out into the Republican Valley with force sufficient to deflect the river temporarily across its flood plain. The railroad bridge across the lower course of the canyon has been damaged by this rush of water.

REPUBLICAN RIVER.

Republican River heads in the table-lands of eastern Colorado many miles east of the Rocky Mountains, and, entering Nebraska in the southwestern corner of Dundy County, flows east about 250 miles across that State before it turns south into Kansas, near Superior.

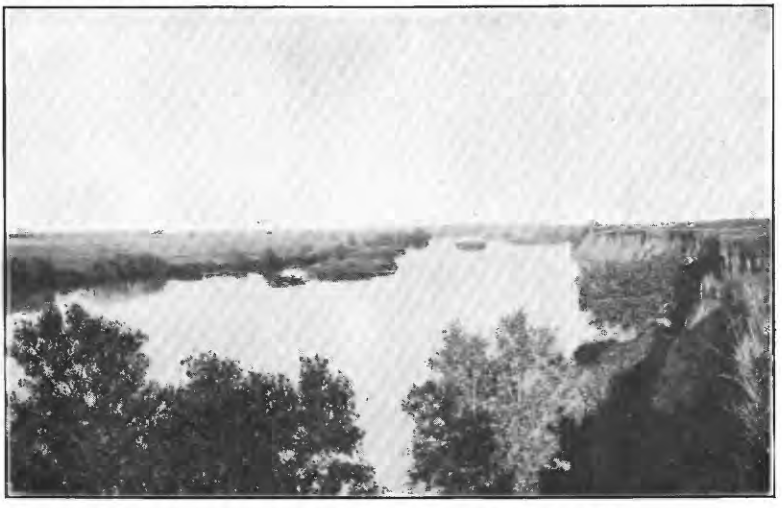
The principal affluents are South Fork, Frenchman River, and Medicine, Sappa, and Prairiedog creeks. In Colorado its valley is mostly in porous Quaternary and Tertiary deposits, but in Nebraska it is excavated in impervious Cretaceous rocks. Throughout its course the river flows over a deposit of alluvium of its own deposition. The depth of the valley bottom below the bordering table-lands and loess plains varies from 200 to about 400 feet.

The stream is mostly shallow and relatively wide and its sandy bed is bordered by low sandy banks, except in places where it cuts into bordering terraces, where the banks are higher and precipitous. The river scours its right bank much more than the left. A typical view of the river is given in Pl. IX, *A*.

Throughout its course the stream is supplied by spring-fed tributaries. In the western counties, where the rainfall is small and direct run-off is rapid, the river bed often is dry in midsummer immediately above the mouths of Buffalo, Rock, and Frenchman creeks, while the flow from these streams revives the flow in the river below their mouths. This loss of water at the surface is due to evaporation, especially where the water is used for irrigation. Such alternating dry and running portions of the course of the river extend as far east as Superior during periods of drought. Only once in twelve years has the river ceased to flow at Red Cloud and Superior. The river water is useful mainly for stock, irrigation, and power. The following data were compiled by Mr. J. C. Stevens, of the United States Geological Survey:

Estimated monthly discharge of Republican River at Benkelman, Nebr., 1895, 1903, 1904.

Month.	Maximum.	Minimum.	Mean.	Total.
1895.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-feet.*
March (30 days)	162	29	78	4,640
April	95	33	59	3,520
May	281	0	25	1,540
June	830	34	155	9,220
July	656	41	120	7,380
August	102	0	34	2,090
1903.				
May (20–31)	71	47	58	1,380
June	81	43	59	3,510
July	112	19	39	2,400
August	61	26	32	1,970
September	47	19	39	2,320
October	54	43	49	3,010
November (1–20)	64	50	56	2,220
1904.				
March	111	46	89	5,478
April	124	30	65	3,870
May	99	23	54	3,310
June	227	46	91	5,430
July	211	5	40	2,520
August	165	10	29	1,780
September	46	0	15	892
October	195	30	61	3,750
November	87	55	65	3,810



A. REPUBLICAN RIVER SOUTH OF BOSTWICK, NEBR.

B. SAND-HILL LAKE, DUNDY COUNTY, NEBR.

Estimated monthly discharge of South Fork of Republican River at Benkelman, Nebr., for the years 1903–1905.

Month.	Discharge in second-feet.			Total.
	Maximum.	Minimum.	Mean.	
				Acre-feet.
1903.				
May (20–31)	57	36	48	1,140
June	65	7	37	2,200
July	36	7	15	922
August	79	7	25	1,540
September (1–5 and 14–30)	22	7	15	655
October	50	22	39	2,400
November (1–20)	65	50	57	2,260
1904.				
March	102	31	60	3,690
April	66	6	21	1,260
May	255	47	92	5,680
June	397	47	132	7,850
July	115	5	39	2,420
August	89	11	24	1,480
September	47	5	13	774
October	115	31	57	3,540
November	66	47	59	3,530
1905.				
March (17–31)	249	96	159	4,730
April	300	52	141	8,390
May	137	52	100	6,150
June	283	21	68.6	4,080
July	152	5	35.4	2,180
August (1–13)	96	21	47.7	1,230

Estimated monthly discharge of Republican River at Superior, Nebr., 1897–1903.

[Drainage area, 22,347 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1897.						
March	650	385	510	31,360	0.023	0.026
April	2,870	620	1,244	74,020	.056	.062
May	1,130	180	420	25,820	.019	.022
June	[a] 750	180	359	21,400	.016	.018
July	4,310	119	922	56,690	.041	.047
August	1,460	94	259	15,920	.012	.014
September	241	0	71	4,220	.003	.003
1898.						
April	[b] 2,130	490	755	44,930	.03	.03
May	1,870	500	1,053	64,750	.05	.06
June	2,300	560	1,235	73.490	.06	.07
July	1,340	220	479	29,450	.02	.02
August	380	100	195	11,990	.01	.01
September	470	185	289	17,200	.01	.01
October	365	145	264	16,230	.01	.01
November	[c] 470	320	382	22,730	.02	.02
1899.						
March	[d] 956	60₁	706	43,410	.031	.015
April	842	375	578	34,390	.026	.029
May	1,800	292	511	31,420	.023	.026
June	4,040	141	531	31,600	.021	.023
July	1,380	209	458	28,160	.020	.023
August	868	136	303	18,630	.014	.016
September	102	6	50	2,980	.002	.002
October	101	24	53	3,260	.002	.002
1900.						
April	1,670	565	909	54,090	.04	.04
May	2,940	320	735	45,190	.03	.03
June	674	250	392	23,330	.02	.02
July	349	67	159	9,780	.006	.007
August	1,280	24	149	9,160	.006	.007
September	2,010	8	156	9,280	.006	.007
October	148	26	69	4,240	.003	.003
November	[e] 162	36	87	5,180	.004	.004

[a] June 1–25.
[b] April 20–30.
[c] November 1–19.
[d] March 19–31.
[e] November 1–24.

Estimated monthly discharge of Republican River at Superior, Nebr., 1897–1903—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Sec.-ft. per sq. mile.	Depth in inches.
1901.						
April	1,510	637	961	57,180	.043	.048
May	622	146	364	22,380	.016	.018
June	480	117	219	13,030	.010	.011
July	154	5	44	2,620	.002	.002
August	856	5	70	4,300	.003	.003
September	4,990	10	1,246	74,140	.056	.062
October	1,490	285	443	27,240	.020	.020
November	1,030	312	419	24,930	.019	.021
1902.						
March	[a] 920	330	675	29,450	.03	.02
April	740	390	555	33,020	.02	.02
May	2,810	335	1,269	78,020	.06	.07
June	3,240	320	1,372	81,640	.06	.07
July	12,490	970	[b] 3,080	[b] 189,360	[b] .14	[b] .16
August	1,920	330	674	41,440	.03	.03
September	10,880	155	1,175	69,910	.05	.06
October	1,990	520	937	57,610	.04	.05
November	970	460	622	37,010	.03	.03
1903.						
March	[c] 7,750	1,260	2,692	96,110	.120	.080
April	1,260	705	918	54,620	.041	.046
May	14,100	845	4,491	276,140	.201	.232
June	6,460	885	1,921	114,310	.086	.096
July	7,820	465	1,948	119,780	.087	.100
August	3,280	520	1,230	75,630	.055	.063
September	700	270	389	23,150	.017	.019
October	390	245	326	20,040	.015	.017
November	690	130	417	24,810	.019	.021

[a] March 9–31. [b] Exclusive of four days' flood discharge. [c] March 14–31.

FRENCHMAN RIVER.

Frenchman River is fed by several tributaries in Chase, Perkins, and Hayes counties and flows southeastward to join the Republican at Culbertson. Only a small part of its drainage basin is within the region to which this report relates. The upper tributary streams are in deep, steep-walled canyons and gather most of their water from springs issuing from the Tertiary. Farther downstream, where the slopes decrease in grade, the valley widens and is cut in Pierre clay. Near its mouth the stream is shallow and from 75 to 100 feet wide. It flows over a sandy bed in which there are small sand bars and islands. At Wauneta, in Chase County, the river falls about 8 feet over a hard ledge of Tertiary rock, as shown in Pl. X, *A*. A flour mill is run by power from this fall.

A. FALLS OF FRENCHMAN RIVER AT WAUNETA, NEBR.

B. SPRING IN DUNDY COUNTY, NEBR.

Estimated monthly discharge of Frenchman River at Palisade, Nebr., for 1895 and 1896.

Month.	Maximum.	Minimum.	Mean.	Total.
1895.	*Second-feet.*	*Second-feet.*	*Second-feet.*	*Acre-feet.*
March	118	98	105	6,460
April	156	107	137	8,150
May	158	111	129	7,930
June	600	50	132	7,850
July	580	54	158	9,720
August	437	64	96	5,900
September	98	68	78	4,640
1896.				
May	200	92	114	7,010
June	800	50	104	6,190
July	145	80	94	5,780
August	92	63	76	4,670
September	89	77	82	4,880
October	89	76	82	5,040

REDWILLOW AND MEDICINE CREEKS.

Redwillow and Medicine creeks are similar to each other in origin and flow, and although they have a long course they carry but a small volume of water. They rise in canyons near Platte River, in Lincoln County, and flow to the Republican through deep narrow valleys in a nearly level upland. Each has sufficient power for the successful operation of flour mills.

BEAVER AND SAPPA CREEKS.

Beaver and Sappa creeks are much alike in flow and drainage area, heading in the vicinity of the Colorado line and receiving the run-off of a considerable portion of northwestern Kansas. They flow northeastward parallel to the Republican, unite in the eastern part of Furnas County, and join the Republican near Orleans. Both creeks flow over a bed of alluvium lying on the Niobrara formation. The volume of water is small, but the flow is constant in the Nebraska part of their courses, where it is augmented by the run-off and by several tributaries fed by small springs. Only one gaging is on record. It was made on Beaver Creek one-fourth of a mile below the mill at Stamford by J. A. Green, July 6, 1904. The surface width below the confluence of the creeks is 21 feet; the area of the cross section of the stream is 33 feet; the mean velocity 95 feet, and the discharge 36 second-feet.

PRAIRIEDOG CREEK.

Prairiedog Creek rises in Kansas, but flows for a few miles through Harlan County, which it enters with volume about as great as that of Sappa Creek. Near its mouth, south of the town of Republican, the creek cuts into the Niobrara chalk, which causes small rapids in its bed. The stream is not now used in Nebraska either for power or irrigation.

LITTLE BLUE RIVER.

Little Blue River is next to the Republican in volume. Its tributaries rise in the loess plains, principally in the vicinity of Hastings, and gather water from the long slopes extending to the brink of the Platte Valley. The general slope of the drainage basin is southeastward, and the river flows into Kansas in the southeastern part of Jefferson County. The drainage area comprises approximately 13,000 square miles, in Webster, Nuckolls, Thayer, and Jefferson counties; in this region the flow is constant, even during periods of dry weather. Much of the water is derived from springs issuing from Quaternary sands and from Dakota sandstone. The river rises considerably during freshets, and during these times has a strong tendency to shift its channel in the sandy bottom lands. During the past year the stream has straightened its course at several places, cutting across some valuable farm lands, notably between Endicott and Steele, south of Alexandria, and near the Chicago, Rock Island and Pacific Railway bridge between Hebron and Gilead. These changes in the channel cause much damage to land, crops, and roadways, and they are much more frequent on this stream than on the Republican.

SPRINGS.

Springs have their source in ground water which issues at the surface under various conditions. The principal horizons at which springs occur in the region are (1) the contact zone between the Tertiary and the underlying Pierre and Niobrara formations, (2) the base of Quaternary materials of western origin where they overlie impervious Cretaceous beds, and (3) the Dakota sandstone, especially when this lies above clay beds.

Many small and a few large springs appear at the first-named horizon, which extends along the entire length of Republican River in Nebraska to its headwaters in Colorado. Most of these springs are located north of the river, the strongest being at or near the heads of tributaries. Among the best examples are those on the Moore ranch northeast of Haigler (Pl. X, *B*), and a spring near Trenton.

In the counties as far west as Hitchcock, and as far east as Franklin, both Tertiary and Quaternary sands yield spring water, but along the tributaries of Little Blue River in northern Thayer and Jefferson counties water comes entirely from the Pleistocene sands. Big Sandy Creek is a good example of a stream which derives its water from these sands.

Spring water from the Dakota sandstones appears to come from two sources. Part of it from distant sources is artesian water escaping along the outcropping area of the formation from eastern Thayer County to the Kansas line. Some of this water flows into the same

streams that receive water from the Quaternary sands. The Dakota sandstone outcrops south of Rose Creek, probably derive their spring water from the local rainfall, the water percolating down to clay beds and then outward to the surface.

LAKES.

In the undissected loess plains much of the rainfall is caught and retained in the soil and in numerous temporary ponds during wet weather. Some of these ponds are 8 to 10 feet deep after exceptionally heavy rains, and while a few contain water throughout the year most of them either remain marshy or dry up during the summer months. Such ponds occupy only a small part of the surface in the level uplands, and they are most frequent in counties lying just north of the eastern part of the region. Some of the wet-weather lakes have been drained and the land thus reclaimed for agricultural purposes.

In the sand hills, where the drainage channels are poorly defined, the rainfall soaks into the sands and at the time of heavy rains water fills the basins sometimes to a depth of several feet. Humus and fine silt carried into the basins help to check the downward movement of the water, causing it to accumulate at the surface during rainy weather. There are several examples of such lakes in Dundy County, notably between the heads of Buffalo and Rock creeks (Pl. IX, *B*).

Storage of surface water by means of artificial ponds has been practiced to some extent, especially near heads of spring-fed streams. Examples of this kind are found in Rock and Buffalo creeks of Dundy County. There are lakes also at various localities where the water is held by mill dams.

UNDERGROUND WATERS.

SOURCE OF GROUND WATERS.

The volume of water absorbed by the ground near the surface varies not only with the amount of precipitation but also somewhat with topographic conditions, which promote or retard surface drainage, and especially with the porosity of the soil. Some of the absorbed water is lost by evaporation and some percolates to lower levels. The loess is porous and the vertical structure of the formation is a favorable feature, but the fine texture of the material greatly diminishes its capacity for absorption. The rate of motion of water downward through the various formations varies with the texture and pressure, the motion being more rapid in coarse sands and gravels than in rocks of finer texture. The Cretaceous clays are of such fine grain that they check the downward motion of the ground water, thus often causing it to accumulate in the more porous overlying sands and

gravels. The thickness of the latter varies from 0 to 100 feet, and the amount of ground water which they hold is very great. The Tertiary and Quaternary sands and gravels, when completely saturated, contain from 25 to 30 per cent or more of water. Owing to underflow, however, the beds are usually not filled to the top but only up to a subsurface plane, which may be level or sloping, known as the " water table."

Water stored underground in this manner is often the accumulation of many years. The amount is increased and the water table raised by an increase in rainfall, and is lowered correspondingly during long periods of drought. This subsurface storage of water is the main supply for springs and wells and is a source of much of the moisture supplied to growing crops.

QUALITY OF UNDERGROUND WATER.

Underground water contained in the different geologic formations varies much in quality, quantity, and accessibility. Tertiary sands and gravels usually carry an abundance of soft to medium-hard water at moderate depths. The water of the other formations is slightly hard, " alkali " or saline, containing minerals dissolved from the rocks during the slow percolation of the water. Pollution by organic matter is also common, especially in surficial deposits. Most of the Cretaceous formations contain considerable soluble mineral matter, and as a result, their waters often are not of good quality. This is especially the case with the Pierre, Niobrara, Carlile, and Graneros formations, the supply from which is often unfit for domestic purposes. The porous sandstone of the Dakota formation usually yields good water in large supply, but it is hard and often heavily charged with iron. Not a few wells in this formation yield water too saline for drinking and house use. Alkali water is most common in regions where the Pierre shale outcrops or lies close to the surface.

The waters from Tertiary sands have wide distribution and are readily accessible. Often they contain but little mineral matter, although water from the alluvium sometimes contains much alkali, derived from the underlying Pierre shale.

DEPLETION OF SUPPLY.

The water supply near the surface is subject to considerable variation in amount, for there is constant evaporation and a natural drainage to lower levels.

The amount of underground water lost by seepage or springs is considerable. It would be much greater, however, were it not for the usual presence of a loesslike alluvium along the seepage horizon

in the main valleys, which checks the rapid flow of water to the surface.

Considerable water near the surface also is lost by evaporation, a factor which increases in importance from east to west. From an open water surface the evaporation averages about twice the precipitation in the western counties of Nebraska. Water stored deep in the soil is not subject to much loss by evaporation. Water drawn from wells, though comparatively inconsiderable in relative amount, is a direct drain on the underground supply.

SHALLOW WELLS.

Water of good quality and in large amounts can be obtained by wells at moderate depths in most of the region treated in this report. The principal sources of supply are the Dakota sandstone, Quaternary sand, gravel, and alluvium, and the Tertiary deposits. Wells are bored, drilled, driven, or dug, and the casings most used are wood, galvanized iron, stone, tile, and gas pipe. In some instances no casing is required.

The shallowest wells are along valleys, and the deepest wells, which vary from 100 to 300 feet in depth, are on the uplands. The local conditions in each county are presented more specifically on later pages in this report.

WEAK AND DRY WELLS.

The volume of water which may be pumped from a well within a given time depends on several factors, the principal one of which is the rate at which water is delivered to the well from a water-bearing formation. This is controlled more by the size of the spaces between the grains of sediment than by the depth to which a well is sunk below the water table, a fact illustrated by a well at N. J. Allen's ranch, 12 miles northeast of Haigler. At first this well ended above the "magnesia" rock and the water was supplied from fine sand and all the water could be pumped out in thirty minutes. When the pump was stopped the water slowly rose again to the level of the water table. Later the well was deepened to reach a bed of coarse gravel, which yielded water in such volume that apparently it was not weakened by three hours pumping with a gasoline engine having an output of over 15,000 gallons. This type of well is duplicated at many other places on the uplands, for the conditions are similar over a wide area. The well on the ranch of Mr. J. McAlee, on the bottom below Benkelman, is one of the best examples of a strong valley well deriving its water from alluvium. This well is 1 foot in diameter and 27 feet deep, and when pumped at the rate of 150 gallons a minute the water level is lowered only a short distance. It then remains stationary during vigorous pumping and as soon as the

engine is stopped the water rises to its normal level in a few seconds. The source of supply here is in coarse gravel lying on Pierre shale.

In some wells the water is supplied from fine sands, and, although the volume of water may be large, yet its movement to the well is so slow that the yield is small. One of the best ways to obviate this disadvantage is to increase the size of the well, which gives a larger reservoir in which the water may accumulate.

Weak wells also result when the water table is greatly lowered by dry seasons.

In the case of some weak wells the supply can be increased by sinking to greater depth, providing of course the Cretaceous shales or chalk rock are not entered.

In some districts wells fail to obtain any water, but these are almost invariably in localities where the surface of either the Niobrara or the Pierre formation rises above the water table. A narrow zone presenting these conditions borders each side of the Republican Val-

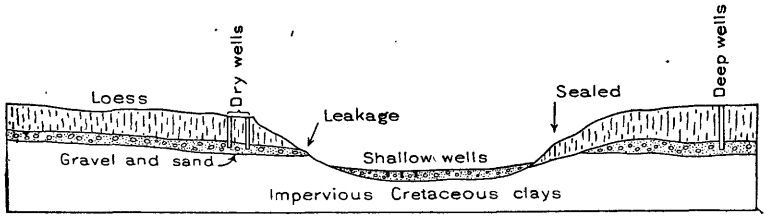


FIG. 2.—Section across a valley in southwestern Nebraska, illustrating the ground-water conditions.

ley throughout its course in Nebraska and extends for some distance up its tributaries. It is due to the fact that the Republican and its tributaries have eroded their valleys from 30 to over 100 feet in depth in the Cretaceous clays, permitting the ground water in the overlying formations to drain out on the slopes. The width of these zones varies considerably and is greatest where the tributary valleys are long and frequent and there are numerous deep ravines. As soon as the well driller strikes Pierre clay or the Niobrara formation he should discontinue the well and move to a point farther from the breaks at the edge of the valley, if an upland well is desired, or to some point on the valley bottom below. The ideal cross section of a valley shown in fig. 2 will serve further to illustrate the conditions described above. The escape of water is checked by loess and terrace materials on the right side of the section shown in this figure.

In T. 7, R. 25, northwest of Cambridge, much trouble has been experienced in obtaining water. A well there, 130 feet deep, reached the Niobrara and found no water, while another well 2 miles farther north tapped the water table and an abundance of ground water at

110 feet. In that region as elsewhere the depth to ground water increases while passing from the edge of the dry-well zone to the higher level upland. There are five dry wells on sec. 36, 12 miles south of Trenton. Near Deer Creek, 7 miles northeast of Cambridge, there are seven such wells on 1 acre of the Sullivan farm, each reaching the Niobrara formations at a depth of over 100 feet. After sinking the holes on the Sullivan farm the driller moved 20 rods northward and obtained plenty of water in a well somewhat shallower.

BLOWING WELLS.

Blowing wells occur in most counties in southern Nebraska, the largest number being in Jefferson, Thayer, Dundy, and Hitchcock. They are present in the loess area where the water level is some dis-

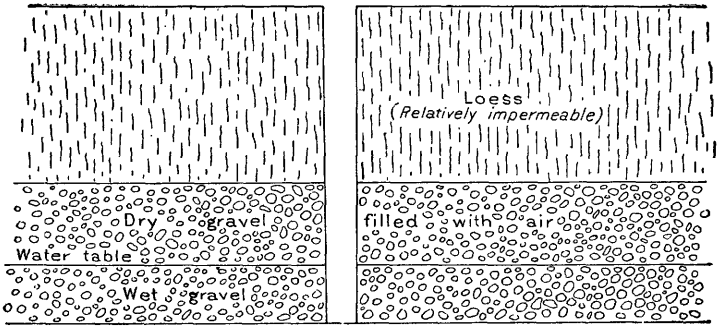


FIG. 3.—Section showing blowing-well conditions.

tance below the top of the underlying gravels, the upper beds of the latter being dry.

The cause of the motion of air in these wells appears to be changes in pressure of the atmosphere with which the periods of inhalation and exhalation closely correlate. Fig. 3 shows the conditions under which "blowing wells" occur.

During the time of high barometer or heavier air pressure air moves down the well into the dry gravel, and when the atmospheric pressure diminishes the air comes out of the well. At times of stationary pressure there is no movement. The well, then, is an artificial opening between the loess-covered gravel, with its spaces filled with air, and the surface, where pressure is frequently changing. The loess is so much less pervious to the air than the gravel is that the movement of air through it is very slow, while the well affords a ready channel for upward or downward movement. The velocity of the movement of course varies with the difference in pressure between air in the gravel and that at the surface, with the porosity of the gravel and of the overlying loess bed, and with the depth and diam-

eter of the well. The strongest blowing is usually in wells of small diameter. Changes in the water level also increase or diminish the thickness of the dry gravel; a rise of the water table to top of the gravel would displace the air.

A well at the ranch of C. E. Weeks, 4 miles northeast of Fairbury, is a good example. It is 118 feet deep and a strong blower.

A well at Harbine, owned by George Wells, will blow the hat off of one's head. Numerous other similar examples occur on the uplands north of Alexandria, Stoddard, Hubbell, Indianola, and Benkelman. The blowing appears to bear little or no relation to the available water supply. During the coldest times of winter much trouble is experienced by the freezing of pipes, due to the inhalation of cold air, and in the well of C. E. Weeks, referred to above, the water pipe sometimes has frozen as far down as 100 feet.

Numerous pumps in the upland wells near Arapahoe have to be pulled during the coldest periods of winter on account of bursted pipes. A safety cock is now placed in most pipes about 30 feet below ground, and in very cold weather it is opened to serve as a drain. By this method and by the use of hot water freezing is often prevented. Blowing wells also are natural barometers and thus indicate approaching changes in the weather.

POLLUTION OF SHALLOW WELLS.

As well water is supplied from the surface of the ground by percolation it is subject to dangerous contamination from drainage from outhouses, barnyards, and pigpens. No part of the farm home should be guarded with more care than the well, for polluted waters are frequently the source of disease. Wells should be cleaned frequently, and curbing that has begun to give odor and taste to the water should be replaced. Often decaying casing will render good water unfit for use. The well should be so situated that surface drainage will be away from the well and never toward it.

In case there are two or more water-bearing formations from which a supply of water for domestic use may be obtained, the well should be located so as to secure the more suitable water. The problem is not so much the amount as the quality, when the supply is to be used for drinking purposes. It should be better understood that shallow poorly kept wells are a certain source of disease, and that their proper location and care is essential for the health of all those using the water.

Along the chalk bluffs in the Republican Valley there is a tendency to place the well below the house and lots, usually well on the valley bottoms, where there is plenty of water but increased possibilities of pollution. At many such places wells can not be sunk above the house because of the Niobrara or Pierre formations in

the valley slopes, which do not yield good water, but even under this circumstance they can be located out of the line of drainage from the barn and other unclean spots. If placed up-valley from the house, lots, and outhouses the chances of pollution are greatly lessened.

WINDMILL PUMPING.

Water is raised by windmills at many places in the valleys and on the uplands from wells of various depths. The primitive method of lifting water by bucket and windlass is now rarely seen, having been supplanted by windmills, there being usually enough wind to propel these for at least part of the day.

IRRIGATION FROM WELLS.

It has been hoped that the wells of the uplands and valley bottoms of the southwestern counties of Nebraska would yield enough water for the irrigation of large areas, but the supply has been found inadequate at most localities. There is, however, sufficient water for use in gardens for raising fruit, vegetables, and flowers, and, to a limited extent, for certain crops. The best known irrigation plant using well water is on the valley bottom a short distance southeast of Benkelman (see Pl. XI, *A*), at the ranch of Mr. J. McAlee, where a 20-acre garden has been irrigated for two years from a single well 27 feet deep. The water is raised by a gasoline engine pumping 150 gallons a minute into a reservoir covering three-fourths of an acre to a maximum depth of 6 feet. During the year 1903, the income from the garden was $960, after losing much by frost.

ARTESIAN WELLS.

One purpose of this investigation was to ascertain the prospects of securing flowing wells, but the results were not altogether conclusive. The Dakota formation, containing a thick mass of water-bearing sandstones, underlies most of the region described and should be expected to yield artesian flows along at least a part of the Republican Valley. It is overlain by impervious clays and shales in the counties from Thayer westward, and while these beds are not of great thickness apparently, no boring thus far drilled in the Republican Valley has reached the Dakota sandstone. Unsuccessful attempts have been made at or near Arapahoe, Indianola, McCook, and 5 miles east of Haigler. The boring at Arapahoe was discontinued at about 912 feet when the drill must have been very near the Dakota sandstone. A weak flow, which continued for a short time, was found at a depth of about 550 feet. A well at McCook, about 405 feet deep, flowed a few gallons a day. The water in both wells appears to come from the Niobrara formation.

There are several unfavorable conditions for satisfactory flows in southern Nebraska. In the first place the outcrop of the Dakota formation extends across Jefferson County and southwestward across Kansas, and the leakage by springs and seeps is so complete that the artesian pressure is finally all lost. To the west there is a gradual rise of pressure toward the intake zone along the mountains, but the rate is low, perhaps not as much as the general rise at the bottom of the Republican Valley, especially from Furnas County eastward. The margin is small either way, and the true condition can be determined only by a boring in the valley sufficiently deep to penetrate the Dakota formation. A second factor is found in the structure of the Dakota formation: The sandstone or water-bearing beds, where exposed in Jefferson County, appear to be interrupted by clay beds which are usually near the middle of the formation, but which may possibly cut off or displace the sandstones locally. If such a condition exists under the western counties the continuous underground motion of the water might be greatly hampered. In general the beds outcropping appear to show a less favorable structure for an artesian supply under heavy pressure than is found along Missouri River in South Dakota and northeastern Nebraska. Wells reaching the Dakota sandstones in Jefferson and Thayer counties often obtain saline water, which is usually under some pressure, but with one exception, not under enough to lift it to the surface.

The Permian beds have been reached by at least two wells in Jefferson County. In one of them 3 miles south of Fairbury and 336 feet deep, saline water rose 200 feet. Near Steele a weak saline flow was obtained at 195 feet. These examples indicate that there is sufficient pressure in the Permian beds to force water to the level of the bottom lands along the river in the southern part of Jefferson County. The quality, however, is unfavorable for domestic and stock purposes.

A few wells in Tertiary deposits find water under slight pressure. A well of this kind, located on the place of Mr. J. W. Kinsley, 10 miles north and 2 miles east of Benkelman, has the water level so near the surface that it could be piped out.

There is a small area of flowing wells about Alexandria on the valley bottom adjoining Big Sandy Creek. It extends some 4 or 5 miles east and west and about the width of the flood plain north and south. The flow was discovered and developed by Mr. E. N. Averill, who has four or five wells. The first well, which was put down in 1899, did not flow at first, but now there are about twenty flowing wells. They vary from 40 to 60 feet in depth; passing through soil, 2 to 4 feet; sands, with first water, 30 to 35 feet; blue clay, about 5 feet; and peaty clay or old soil to water in coarse alluvial sand or fine gravel. Most of the wells are bored 11 inches in diameter and cased with wood, though in some the casing is galvanized iron. One of the

A. McALEE IRRIGATION PLANT AT BENKELMAN, NEBR.

B. WINDMILLS IN SAND HILLS OF WESTERN NEBRASKA.

Averill wells, only 2 inches in diameter, flows 50 gallons per minute, has a head of 4 feet, and temperature of 49° F. The water is forced by a ram to a 500-gallon tank 600 feet distant and 24 feet above the well, from which it is piped through Mr. Averill's residence.

The other wells flow into a pond used as a source of ice, for boating, and for fish culture. This pond is 250 by 350 feet across and 5 to 6 feet deep. The first well completed at the pond (see Pl. XII, *A*), flowed 110 gallons per minute.

The source of water appears to be in the Dakota sandstone which immediately underlies the alluvial valley filling. The basin, as has been shown, is small and local, and the pressure is sustained by a clay bed which overlies the water-bearing sand.

WATER SUPPLY, BY COUNTIES.

DUNDY COUNTY.

All Dundy County is underlain by the Pierre shale, the surface of which rises 25 or 30 feet above the river at Max and Benkelman and about 100 feet in the vicinity of Buffalo Creek and Haigler. Next above is the Tertiary, which in the northwestern part of the county has been worked over into dune sands and in other sections is overlain by loess. The alluvium along the Republican averages between one-half and three-fourths mile wide, exclusive of the higher terraces.

South of the river the water supply varies considerably as to amount and quality and wells often fail to obtain a sufficient supply, while in the southeast wells ending in the Pierre shale afford bad water. Along the bottom lands water is obtained at depths ranging from 15 to 60 feet, the deeper wells being located on benches. Some of the water varies in quality from hard to alkaline. At Benkelman a good supply of water is reached at depths varying from 20 to 112 feet, the deeper wells being high on the valley slope. The well at Mr. J. M. McAlee's irrigation plant at Benkelman has been described on page 43. An equally strong well, also sunk in the alluvial gravels, affords water for the Burlington and Missouri River Railroad. It is reported to have supplied 50,000 gallons of water in four hours.

Farther up the Republican Valley the best supplies of well water are secured from the alluvium on the north side. At Haigler, located on a bench on the south side, the wells are deeper than usual, being from 45 to 60 feet deep. They afford water of poor quality, owing to the underlying Pierre shale. A town well is used as a public watering place, but the water now used for domestic purposes and drinking is hauled from a shallow well near the river.

In the uplands north of the river the ground-water table varies considerably in depth. In the sand-hill region it is reached by shallow wells varying from 10 to 80 feet in depth, while on the highest part of the divide, between the Frenchman and the Republican, the

depth is from 200 to 308 feet, the amount decreasing to the south and the west. In all this part of the county the water table is not easily lowered by the hardest pumping. The water is usually soft or medium hard. At most places it occurs in two horizons in the Tertiary, one above and the other below a fairly definite zone of "magnesia" rock, parts of which are extremely hard and difficult to dig or drill through. Some wells derive their water from the rock. Most of the recent deeper upland wells are tubular, but during the early occupation of the country dug wells were most common. In one dug well three and one-half days were required for penetrating a hard bed 3 feet thick.

Tributaries of the Republican from the north are fed by some of the strongest springs in Nebraska, but while most of the strong, heavy springs are located in the north-side valleys there are also a few on the south. A notably strong spring occurs on the Drummond place, 6 miles northwest of Haigler, from which the water is piped one-fourth mile to the stock yards and house.

Representative wells of Dundy County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
McAlee, J. M	Benkelman, on bottom	27	24	Sand and gravel to Pierre clay; water in gravel.
Arla Cattle Co	Parks, on Rock Creek bottom	28	12	Soil, sand, and gravel.
Allen, N. J	Sec. 20, T. 1, R. 40, near bottom	30	10	Dry sand 12 feet; coarse wet sand to water in gravel.
Larned, William	Sec. 33, T. 1, R. 41, near bottom	40	20	Soil, loam, and sand.
Brady, James	Sec. 25, T. 1, R. 42, on bottom	42	8	Soil, gravel, and Pierre shale.
	Sec. 31, T. 2, R. 36, on bottom	30	10	Soil and sand.
Tockler, A. A	Sec. 14, T. 2, R. 38, on upland	80	.....	Soil and sand 27 feet; "magnesia" rock to water.
Allen, N. J	Sec. 19, T. 2, R. 40, sand hills	63	30	Soil, sand, and black loam 27 feet; gravelly sand 2 feet; quicksand 18 feet; "magnesia" rock 7 feet to gravel.
Richards, I. B	Sec. 14, T. 3, R. 36, highland	209	3½	Loess 100 feet; soft sand rock 8 feet; sand 5 feet; clay 20 feet; rock 58 feet; clay, rock, sand, and gravel to water.
Lewis, F. B	Sec. 1, T. 3, R. 37, low slope	48	13	
Larison, F. M	Sec. 8, T. 4, R. 37, highland	225	.....	
Johnson, M. M	Sec. 29, T. 4, R. 36, highland	245	15	Soil, loess, and "magnesia" rock.
Nesmith, M. W	Sec. 17, T. 4, R. 36, highland	238	.....	Soil, loess, sand, and "magnesia" rock to water.
Ough, William	Sec. 17, T. 4, R. 37, highland	200	14	Black soil 5 feet; clay 140 feet; sand 12 feet; "magnesia" 30 feet; rock 5 feet; gravel 8 feet.
Krausmick, E	Sec. 24, T. 4, R. 37, highland	262	15	Soil, loess, and "magnesia" rock.

HITCHCOCK COUNTY.

The principal streams in Hitchcock County are Republican and Frenchman rivers and Driftwood Creek, the valley slopes of which are formed by Pierre clay, Tertiary deposits, and loess. Frenchman River is a valuable source of irrigation water, while the Republican varies greatly in volume.

A. ARTESIAN WELL AND RESERVOIR AT ALEXANDRIA, NEBR.

B. DAM IN REPUBLICAN RIVER AT SUPERIOR, NEBR.

Springs are numerous, and they supply much water for domestic purposes and stock. Most of them are located north of the Republican and issue at scattered localities from the Pierre-Tertiary contact. The explanation of their irregular distribution is the varying height to which the impervious shales and clays rise above the river, and the presence in places of a covering of either loess or alluvium, which often prevents the surface escape of water. In the vicinity of Trenton the Pierre-Tertiary contact extends along the valley slopes at or near the surface at a level about 20 feet above the bottom land, and springs often appear along it. A few miles east and west the water horizon is more deeply covered on the slopes, and springs cease. About midway between Trenton and Culbertson the Tertiary contact extends down nearly to the level of the river, and the spring horizon is lowered correspondingly. Springs south of the river lie principally on the north branch of the Driftwood, only one of good size being found on the south branch.

Most of the uplands are covered by loess underlain by Tertiary water-bearing sands and gravels with occasional beds of the so-called "magnesia" rock. Impervious Pierre shale underlies all of the county below the Tertiary and prevents water from sinking below the base of the Tertiary deposits.

Bottom lands along the Republican in Hitchcock are broader than in Dundy County. Those of the Frenchman vary from $\frac{1}{2}$ to 1 mile in width. It is stated that the average depth of wells in the bottom lands in the county is from 25 to 35 feet. An abundance of good cool water is usually obtained in coarse alluvial sand or gravel just above the Pierre shale, and while wells often reach this shale, they do not penetrate it. The water table in the alluvial beds rises and falls with the river near the channel, but the influence is local. The quality of the water at places along the outer edge of the flood plain near the Pierre shale slopes is often unsatisfactory. This condition is found at Stratton, where the supply varies from good to bad from wells averaging 30 feet deep. Most wells in Trenton are driven. Several years ago a well was sunk near the depot of the Burlington and Missouri River Railroad in that town to a depth of 300 feet. No accurate record was kept, but doubtless the drill penetrated the Pierre shale and may have extended a short distance into the Niobrara formation.

Wells on the upland in this county resemble those in the eastern part of Dundy County. On the higher lands near the Frenchman they are often deeper, one being 347 feet. It passed through soil, loess, and Tertiary rock, sand, and clay, to water-bearing gravel. The depths on the uplands between the Republican and the Frenchman vary from 100 to over 300 feet, and the first water is always found below thick beds of "magnesia" rock, and usually above a bed

of clay. The second water lies in coarse sands and gravel. Blowing wells are not uncommon where there is a bed of dry gravel above the water-bearing horizon. Water in the deep wells on the upland is said to be warmer and softer than that obtained along the Republican bottom. It is claimed that there is a notable difference between the waters of the upland wells and those in Trenton.

The deepest wells on the uplands in the southern part of the county are 220 to 240 feet, and in some of them 85 feet of "magnesia" rock have been encountered above water. On the school section, 12 miles south of Trenton, 5 dry wells were put down, all ending in Pierre shale.

Representative wells of Hitchcock County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Powers, J. H.	Sec. 16, T. 1, R. 32, upland	96	12	Soil, 2 feet; loess, 1 foot; silt to within 1 foot of water-bearing sand, and gravel at bottom.
Brumley, M. M.	Sec. —, T. 2, R. 35, upland	90	8	No record.
Frey, J. W.	Sec. 14, T. 2, R. 33, upland	127	10	Do.
Small, John	Sec. 3, T. 2, R. 33, bottom	13	6	Do.
Miller, C. J.	Sec. 5, T. 3, R. 33, upland	196	12	Black loam, 50 feet; soft rock, 80 feet; dry sand, 2 feet; sand 64 feet; water in sand above rock.
Morgan, T. D.	Sec. 34, T. 3, R. 33, upland	100	7	Black soil, 4 feet; loess, 86 feet; sand and gravel, 16 feet
Powers, C. R.	Sec. 35, T. 3, R. 33, upland	108	.....	Black soil, 3 feet; loess, 70 feet; sand, 30 feet; gravel, 5 feet.
Williams, J. M.	Sec. 12, T. 4, R. 32, lowland	42	.....	Soil, clay, and sand to water.

REDWILLOW COUNTY.

The streams of most importance in Redwillow County are Republican River and Redwillow, Driftwood, and Beaver creeks. They flow in rather wide bottom lands from 200 to 400 feet below the highest uplands. The underlying formations are the same as those found in the next county west, except that near the eastern border the Pierre thins out and the Niobrara gradually rises so that it attains an elevation of 100 feet above the river near Cambridge.

Wells on the bottom land range from 20 to 50 feet in depth. At McCook large amounts of water are drawn from this source for railroad and city use, six large wells having been dug on the first bottom to a depth of 26 feet to the top of the Pierre shale. At Indianola the water lies from 12 to 20 feet below the surface, but most wells are driven to gravel at a depth of 45 or 50 feet. A few wells near the valley slopes in the northern part of the town reach ocherous Niobrara beds and yield a poorer quality of water. On the broad bottom lands near the mouth of Redwillow Creek water lies within a few feet of

the surface, and at the Redwillow store a well is driven 20 feet in the soil and sand. In the uplands south of Indianola the water is in Tertiary rock and gravel, and is reached by wells from 100 to 260 feet in depth, most of them being 140 to 160 feet deep.

It is reported that there are good water supplies in the uplands south of Indianola in the region where the formations dip westward. Farther southeast, in the area of ocher and flint, dry wells are common. In the highlands north of Indianola wells range from 150 to 300 feet in depth, and northwest of Cambridge from 100 to 125 feet.

The water table in the uplands in this county lies approximately level, a feature due to the configuration of the surface of the underlying impervious beds, which rise 100 feet above the river near Cambridge and only a few feet above at McCook.

Springs, though found at a number of places in the county, are not as large nor as numerous as in adjoining counties.

A deep boring at McCook has been reported as having penetrated 405 feet[a] of the Pierre shale, but for most of the distance it was in Niobrara formation, of which it did not reach the bottom. The flow is weak and unfit for use.

Representative wells of Redwillow County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Schippe, G. P.	Lebanon, 7 miles E. of, lowland.	48	6	Bench and clay.
Bennett, Donald	Lebanon, 5 miles E. of, lowland.	40	.....	Bench and clay; loess.
Brandt, Fred	Wilsonville, 6 miles W. of, upland.	160	3	Loess, rock, clay, sand; small supply.
Brockman, Frank	Wilsonville, 5 miles W. of, upland.	120	3	Loess, clay.
McMurrin, D. H	Sec. 20, T. 1, R. 30, upland	170	7	Loess and magnesia rock.
Anderson, Andrew	Sec. 11, T. 1, R. 30, upland	27	5	Loess and rock.
Caldwell, L. C	Sec. 10, T. 1, R. 30, upland	155	4	Sand, loess, magnesia rock.
Benjamine, W. A	Sec. 23, T. 1, R. 30, upland	229	8	Soil, loess, rock, sand, clay, gravel.
Moore, Frank	Sec. 24, T. 2, R. 26, upland	150	.....	Soil, soft sandstone, 24 feet; coarse gravel, 4 feet; small supply.
Reper, Geo. P	Sec. 3, T. 2, R. 29, on slope	70	.....	Soil, gravel, sand.
Rodgers, E. E	T. 2, R. 29, 3 miles SW. of McCook.	75	10	Loess, sand.
Lincoln Land Co	Sec. 29, T. 3, R. 29, McCook	405	407	Sand, and Pierre and Niobrara formations; small flow.
Boyce, N.	Boxelder post-office, 2 miles E. of, upland.	162	10	Soil, 2 feet; loess, 60 feet; Tertiary rock, 80 feet; Tertiary rock and sand, 18 feet; Pierre 2 feet.
Sharp, William	T. 4, R. 30, 7 miles NW. of McCook, upland.	240	4	Loess, rock, gravel.

[a] Another deep boring in progress in 1905, with a depth of over 700 feet, was not deep enough to reach the base of the Graneros formation. Some sandstone, penetrated at a depth of about 700 feet, appears to belong to a bed which usually occurs near the top of the Carlile formation.—N. H. D.

FURNAS COUNTY.

The principal streams in Furnas County are Republican River and Medicine, Beaver, and Sappa creeks. Only a small portion of the course of Medicine Creek lies in the county.

Springs are found in several localities, but are not an important source of supply. Those used most are south of the river between Arapahoe and Edison, northeast of Beaver, and about midway between Cambridge and Holbrook. Seepage springs are common along Sappa Creek near the Nebraska-Kansas line and in the small creeks near Arapahoe.

Well water obtained on bottom lands along the valleys is usually good, but at places it contains alkali, especially in shallow wells on the first bottom. Most wells at Cambridge are on the bottom lands and on an average are driven 35 feet to second water; the first water, somewhat alkaline, is reached at 10 to 15 feet. In Holbrook, Arapahoe, Edison, and Oxford similar conditions prevail, except that in Arapahoe the second water is found only in a few localities and dry wells are more frequent. These dry wells are due to the Pierre shale rising so high as to cut off the ground water.

At certain points, as at the park well, the alluvium deepens locally. The park well is 8 feet in diameter and 44 feet deep; below its bottom four 3-inch sand points extend to a total depth of 48 feet.

In Wilsonville, Hendley, and Beaver the water supply is derived from alluvial sands and gravel lying immediately above Cretaceous shale. At Wilsonville first-water wells are about 20 feet deep. The second water lies in sand under clay about 18 feet below the first water, and is reached by wells 35 to 40 feet in depth. At Hendley second water is obtained in wells 40 feet deep. Conditions along the Beaver and Sappa bottoms are similar to those at Wilsonville and Hendley, but there are dry wells at places.

Wells on the uplands between the Republican and Beaver vary in depth from 100 to 260 feet, with an average of about 150 feet. They pass through much Tertiary rock. On the ranch of William Dickerson, between Beaver and Arapahoe, 100 feet of rock were encountered. In the well on the ranch of William Rone, 6 miles south and 2 miles east of Arapahoe, the water rises considerably. In a well 7 miles north of Beaver the water rises nearly to the surface, and might be drained out, giving a continuous flow.

On the slopes near the valley bottoms much trouble has been experienced with dry wells, but this feature is less frequent north of the Republican than south. The best known dry-well areas are located east of Hendley, northeast of Beaver, and on the slope south of the Republican, the last named extending nearly across the county. The wells in most cases end in the Pierre shale, at an elevation of

from 20 to 40 feet above the level of the river. In the southwestern part of the county they end in the Niobrara at still higher levels.

On the upland north of the river the water table is from 100 to 140 feet below ground, varying with the distance from the valley. The second water lies in gravel about 40 feet below the first, the two being separated by rock. Some wells, extending only to first water, dry up during times of drought.

Tubular wells are losing favor in Furnas County. The points clog up by the deposition of mineral matter within a few years, and as a result they have to be pulled and cleaned in order to obtain a necessary supply of water.

Prof. A. d'Allemand, of Arapahoe, furnished the writer with a log of the 912-foot boring drilled in 1894 at that town, but it is difficult to make out a very accurate section from the log. It was discontinued on account of a disconnected drill which was not removed from the hole. The drilling ended in the Graneros shale, apparently near the Dakota.

Representative wells of Furnas County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Young, L. W.	Sec. 3, T. 1, R. 25	85	.....	Sand and sand rock alternating.
Anderson, R. A.	Sec. 21, T. 1, R. 25, upland	190	.....	No record.
Landgrun, John	Sec. 9, T. 1, R. 24, upland	180	.....	Loess, sand, Tertiary rock.
Burns, G. C.	Sec. 25, T. 2, R. 25, bottom	38	12	Terrace-alluvium and gravel
Johnston, Sam	Sec. 31, T. 2, R. 25, bottom	40	8	Do.
McComb, J. P.	Sec. 31, T. 2, R. 25, bottom	40	10	Do.
Hanug, L. P.	Sec. 22, T. 2, R. 24, upland	109	10	Loess, clay, sand; small supply.
Do	Sec. 23, T. 2, R. 24, upland	85	10	Do.
Pierce, C. H.	Sec. 27, T. 2, R. 24	40	15	Loess, clay, Niobrara.
Snodderly, Henry	Sec. 30, T. 2, R. 24	30	3	Tertiary rock to gravel and water.
Larson, Victor	Four miles NW. of Hendley	186	5	Loess, sand, Tertiary rock and shale: small supply.
Powell Bros.	1½ miles E. of Hendley	200	None.	Loess, shale.
Daniels, M.	Sec. 25, T. 3, R. 21, upland	186	6	Loess, sand.
Zehe, Peter	Sec. 24, T. 4, R. 23	35	7	No record.
D'Allemand, A.	Arapahoe	36	8	Loess-like clay, clay, gravel.
Vanralin, I. J.	Sec. 18, T. 4, R. 23	35	.....	Soil, sand.
Daniels, S. W.	Sec. 19, T. 4, R. 20, lowland	78	60	Soil, clay, sand, gravel.
Trammel, J. W.	Oxford	65	18	Soil, loess, sand, and water, rock, gravel.

HARLAN COUNTY.

Pierre shale underlies most of Harlan County, but the Niobrara chalk rock is exposed along lower levels of the principal valleys.

A sufficient supply of good water is obtained in most parts of the county, yet dry wells are not uncommon in or near towns along the Republican and at places on the uplands near Prairiedog Creek. Wells on the first bottom of the Republican range from 12 to 30 feet in depth. Those on the terrace in the lower part of Alma vary from 45 to 50 feet; in the north part of that town they are about 70 or 80

feet, while at a higher level on the slope the depths are somewhat less, a condition hardly to be expected. The water table lies at about the same depth under the benches and first bottom at Alma, Orleans, and Republican, and the wells at each place are similar, except that more difficulty has been experienced with dry wells at Orleans than at the other towns named. At Stamford it has been found difficult to obtain good water. The town is located on a high bench in which the Pierre shale rises above the water table.

On the uplands between the Republican and the Prairiedog valleys, the water is contained in Tertiary sands and gravels beneath a bed of rock; the wells range from 100 to 150 feet in depth, the deepest one, 170 feet, being an exception.

At a few miles distant from the river on the high land north, water is usually obtained from Tertiary gravels lying beneath rock. Farther away from the river it is reached in sands lying above the rock. The deepest wells are in the vicinity of Ragan, one being 260 feet.

Wells in the northeastern part of the county, where the shallow lakes occur, vary from 140 to about 200 feet in depth.

Important springs are found along the Prairiedog, northeast of Alma, and at several other localities.

Representative wells of Harlan County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Moore, W. R	Sec. 4, T. 1, R. 19, upland	70	6	Sand-lime rock and clay 20 feet; then rock and sand to water.
Gillispie, D. O	Sec. 3, T. 1, R. 17, on slope	54	.....	Soil, sand, clay, sand.
Haskins, M. H	Sec. 15, T. 1, R. 17, bottom	27	.....	Soil, clay, sand.
Cook, J. M	Sec. 15, T. 2, R. 20	71	.....	No rock.
Smith, James	Sec. 15, T. 2, R. 17, upland	100	5	No record.
Klein, C. F	Sec. 4, T. 2, R. 20, upland	122	8	Do.
Popert, M	Sec. 3, T. 2, R. 20, bottom	40	.....	Soil, clay.
Do	Sec. 4, T. 2, R. 20, upland	117	.....	No record.
Giles, E. W	Sec. 7, T. 3, R. 20, bottom	70	46	Loess and sand; stopped on rock.
Peck, George	Sec. 19, T. 1, R. 17, upland	90	10	Loess 50 feet; sand 40 feet.
Hutchinson, M. L	Sec. 35, T. 4, R. 20	50	.....	Soil, clay, sand, gravel.
Uebel, G. W	Sec. 20, T. 4, R. 20, upland	215	70	Soil, loess, Tertiary rock, sand and gravel to Pierre shale.
Pettygrove, N. A	Sec. 17, T. 4, R. 20, upland	140	20	Soil, loess, sand, gravel.
Bayley, Mrs. D	Sec. 21, T. 4, R. 20, upland	228	83	Soil, loess and Tertiary rock, sand, and gravel on Pierre shale.

FRANKLIN COUNTY.

The underlying impervious beds in Franklin County are the Niobrara chalk rock, which underlies the entire area, and the Pierre shale, which is limited to the western part. The first-named formation rises east of Naponee, carrying the water table high above the river.

The water-bearing beds are the same in this county as in Harlan, but a larger amount of well water is derived from the upland sands and gravels. The locality in which it is most difficult to secure an adequate supply of good water is south of the river, where the wells are usually dry or contain water of poor quality. Their depths average about 100 feet near the State line.

On the lowest bottom lands the water is at a depth of 10 to 20 feet. At Naponee plenty of water is obtained from wells 30 to 40 feet deep. About Bloomington and Riverton there are many unsuccessful wells. A well at the foot of the slope at Bloomington is 46 feet deep, ending in gravel. Another, three-fourths mile north, on the slope is 60 feet deep, supplying good water. At Franklin water is obtained in coarse sand lying above the Niobrara chalk rock.

In the uplands north of the river the water table varies from 100 to about 200 feet in depth, the amount increasing with the altitude. At Moline the average depth to water is about 160 feet, and in the vicinity of Upland it is about 150 feet. In a well at the ranch of James Grant, 2 miles south of Macon, accounted one of the best on the first ridge, the water level is 142 feet below ground. In the vicinity of Campbell the depth to the water table ranges from 150 to 190 feet, and wells vary in depth from 170 to about 200 feet, being shallower along the depressions.

This county has many small springs which feed the creeks north of the river. A good example is the W. E. Ewing spring, three-fourths mile northeast of Franklin. It is used for dairy, house, and stock purposes, and eventually may be piped to Franklin for town use. The fall from the spring to the main part of the town is between 60 and 70 feet.

Representative wells of Franklin County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Miller, W. A	Sec. 11, T. 1, R. 15	20	3	Soil, sand, and gravel to Niobrara chalk.
Hoffhenhe, George	Sec. 2, T. 2, R. 14, upland	130	5 or 6	No record.
Davis, Will	Sec. 11, T. 2, R. 14, upland	132	6	Do.
McGinley, H	Sec. 13, T. 2, R. 14, upland	135	6	Do.
Baker, D. W	Sec. 2, T. 2, R. 14, upland	154	5	Do.
Bauerle, G	Sec. 21, T. 2, R. 16, upland	120	15	Sandy loam and clay; sand at bottom.
James, J. H	Sec. 33, T. 3, R. 13, lowland	36	20	Coarse gravel.
Postmaster (Macon, Nebr.).	Sec. 27, T. 3, R. 15	170	.....	Soil, 125 feet; sand, 50 feet.
Byerly, Levy	Sec. 29, T. 3, R. 15	185	.....	Clay, 120 feet; sand, 65 feet.
Zulauf, Chas	Sec. 20, T. 3, R. 17, highland	230	.....	Black soil and sand.
Dunn, John	Sec. 20, T. 3, R. 16, highland	220	15	No record.
Amman, Paul	Sec. 17, T. 3, R. 16, highland	231	15	Do.
Hansen, J. Martin	Sec. 28, T. 4, R. 14	170	15	Black soil, clay, sand, and gravel.
Lorain, H. B	Sec. 20, T. 4, R. 14, highland	151	12	Sand and clay.
Hansen, Nelson	Sec. 16, T. 4, R. 14	187	.....	Clay and sand to water-bearing gravel.

WEBSTER COUNTY.

The underground water conditions in Webster County resemble those described as existing in the eastern part of Franklin County, but the wells average somewhat shallower. Most wells south of the river are in the bottom lands of small ravines, where the chalk rock affords a limited supply of water of inferior quality.

In the uplands north of the river water is obtained from sands and gravel lying between the loess and the chalk rock. It is soft to medium hard, and of good quality. The depths vary from 60 to 100 feet, the deepest wells being in the northwestern part of the county. About Blue Hill and Rosemont the depth to water averages less than 100 feet.

Taken as a whole, the county is supplied with an abundance of good water. Dry wells are found south of the river and at a few places near it on the north. At the ranch of John Griffith, 2 miles west of Red Cloud, a well was driven 225 feet, passing through soil, sand, and the Niobrara chalk rock to the Carlile shale, but it yielded no water. A well in the northern part of Red Cloud extends through loess, sands, and the Niobrara formation to the Carlile shale. The depth is 265 feet, and the water unfit for use.

Inavale, Red Cloud, Amboy, and Guide Rock derive their water supply from alluvial sands and gravel at depths ranging from 20 to 50 feet.

Springs feed most small creeks north of the river. One of the strongest south of the river is about 5 miles from the bridge at Red Cloud.

Representative wells of Webster County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Wild, George	Sec. 32, T. 1, R. 12, ravine	36	10	No record.
Noble, N. S.	Sec. 30, T. 1, R. 12, ravine	30	6	Soil, clay, sand.
Sutton, Oliver	Sec. 21, T. 1, R. 12, ravine	30	10	Do.
Dickerson, F. A	Sec. 5, T. 1, R. 9, slope	60	10	Soil, clay, sand, gravel.
Crabill, William	Sec. 7, T. 2, R. 11, slope	88	10	Loess, gravel, sand.
Bondren, Pierre	Sec. 10, T. 3, R. 12, upland	190	6	Soil, 3 feet; loess, sand.
Bean, Emory	Sec. 22, T. 3, R. 12, upland	140	5	Soil, 3 feet; loess, 90 feet; coarse sand, quicksand, pebbles, gravel.
Guerens, Louis	Sec. 5, T. 3, R. 12, upland	180	4	Soil, loess, gravel, sand, small pieces of rock.
Erickson, Mary	Sec. 20, T. 3, R. 11, upland	130	4	Loess, gravel with occasional pieces of rock, and sand.
Snee, Mary	Sec. 35, T. 4, R. 12, upland	160	6	No record.
Hall, Mrs. H. W.	Sec. 14, T. 4, R. 11, upland	95	12	Soil, loess, sand, blue clay, sand.
Mattock, J. A	Sec. 3, T. 4, R. 11, upland	100	25	Soil, loess, broken pieces of magnesia, blue clay, sand.
Turner, Mrs. S. F	Sec. 2, T. 4, R. 11, upland	150	30	Loess, sand, blue clay, gravel, blue clay, sand.
James, J. A	Sec. 12, T. 4, R. 10, slope	82	8	Loess to sand and water.
Buschow, F. C.	Sec. 10, T. 4, R. 10, slope	76	5	Loess to sand.
Blue Hill	Sec. 9, T. 4, R. 10	200	70	Loess, sand, and gravel.
Buschow, A	Sec. 4, T. 4, R. 10, upland	160	12	Do.
Choats, C.	Sec. 17, T. 4, R. 9, upland	85	18	Loess, sand.
Nelson, Peter	Sec. 16, T. 4, R. 9	58	27	Loess.
Buzzard, S. H	Sec. 8, T. 4, R. 9	50	30	Do.

NUCKOLLS COUNTY.

In the uplands of Nuckolls County well water is obtained from sand, often quite fine, lying on the Niobrara formation and Carlile shale at depths ranging from about 60 to 110 feet. In places near valleys where the bed rock is exposed or only thinly covered by sand and soil considerable difficulty has been experienced in obtaining water in sufficient amounts and of a suitable quality. Wells south of the river are much like those similarly located in Webster County. At Nelson certain chalk ridges and dry sand basins have been the cause of unsuccessful wells, while in other locations, in some cases not far away, good wells have been secured.

Towns on benches along the Republican derive a suitable water supply from alluvial sands and gravels.

There are several strong springs in this county, both north and south of the river. The most notable is about 8 miles northwest of Superior. It supplies water for 500 to 1,500 head of cattle.

Representative wells of Nuckolls County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Henderson, C. H	Sec. 23, T. 1, R. 8	35	.....	No record.
Reid, Thomas	Sec. 24, T. 1, R. 7	40	11	Soil, loess.
Howsick, E. W	Sec. 23, T. 1, R. 7	51	1	Loess, 30 feet; black clay, 10 feet; sand with water at 46 feet.
Spahn, Geo. S	Sec. 14, T. 1, R. 7	30	5	Loess, shale.
Spahn, Geo. S	Sec. 4, T. 1, R. 7	70	17	Loess, sand, chalk rock.
Henderson, A. J	Sec. 22, T. 1, R. 6	30	3	No record.
Whiting, Mabel	Sec. 26, T. 1, R. 6	48	3	Water in.
Churchill, C. E	Sec. 21, T. 1, R. 5	104	8	Soil, loess, sand.
Kruse, John	Sec. 23, T. 2, R. 8	75	8	Sand and gravel.
Coleman, James	Sec. 27, T. 2, R. 8	40	15	Do.
Yohe, D. M	Sec. 22, T. 2, R. 8	36	5	Sand to water.
Middletown, Wm	Sec. 15, T. 2, R. 8	65	20	Loess, sand, Niobrara chalk.
Stien, C. N	Sec. 14, T. 2, R. 8	72	9	Loess, sand, gravel.
Elledge, Chas	Sec. 13, T. 2, R. 8	72	4	Loess, sand.
Bishop, C. A	Sec. 9, T. 2, R. 8	75	4	No record.
Shaw, William	Sec. 3, T. 2, R. 8	70	4	Some rock.
Baker, W. A	Nelson	90	20	Dark loam, fine sand, clayey to bottom.
Kimmerer, Ira	Sec. 24, T. 2, R. 6	48	.....	Loess, sand.
Ruskin	Sec. 15, T. 2, R. 5	120	10	No record; town pump.
Smith, J. C	Sec. 26, T. 3, R. 8	40	20	Black loam, loess, chalk rock.
Beachey heirs	Sec. 34, T. 3, R. 8	70	3	Soil, loess, sand, rock, gravel.
Brockman, M	Sec. 11, T. 3, R. 8	90	.....	No record.
Nesbit, J. B	Sec. 14, T. 3, R. 7	28	8	Do.
Wehrman, F. A	Sec. 17, T. 3, R. 7	80	15	Loam, loess, sand, shale.
Montgomery, D. W	Sec. 8, T. 3, R. 5	35	6	Soil, sand.
King, William	Sec. 30, T. 4, R. 8	90	12	Loess, sand, gravel.
Shell, J. F	Sec. 8, T. 4, R. 8	50	9	No record.

THAYER COUNTY.

The water supply of the upland wells of Thayer County comes from sands and gravels lying on the Carlile and Greenhorn formations, the depth ranging from 70 to 150 feet. At a few places the sands and gravels are dry, as at Byron, where much trouble has been experienced in securing good water for the town. This condi-

tion probably is due to the fact that the Carlile shale rises and displaces the water-bearing beds. Fortunately the Dakota sandstone lies only about 300 feet below the surface at Byron, and its water is of good quality in that part of the county. Wells recently sunk to this source afford an abundance of water, and under pressure sufficient to raise it more than 50 feet.

The Dakota formation underlies all the western part of the county at a depth of from 300 to 350 feet, and appears to contain less salt than farther east. Along the Little Blue Valley and at places near Rose Creek the water obtained from wells in this formation is somewhat salty, and although in some cases it is not too much so for use, in others it is decidedly objectionable.

The Carlile and Graneros shales outcropping along the Little Blue River and Rose Creek valleys contain but small amounts of bad water, unfit for domestic purposes. The Greenhorn limestone affords water of fair quality to a few wells.

Alluvial sands and gravels are the source of most water supplied to towns located on bottom lands. At Hebron wells averaging from 30 to 40 feet deep extend through alluvium to limestone. The small artesian basin at Alexandria has been described on page 44.

Wells at Hubbell vary in depth from 30 to 40 feet, and their supply diminishes somewhat in dry weather.

Representative wells of Thayer County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Webber, Fred	Sec. 36, T. 1, R. 4	315	100	Loess, sand, 50 feet; shale, 160 feet; limestone, 9 feet; shale to 315 feet.
Gaston, Nelson	Sec. 31, T. 1, R. 3	88	8	Loess, 20 feet; sand, 68 feet.
Forsdick, Stephen	Sec. 35, T. 1, R. 3	150	.....	No record.
Baldwin, D. J	Sec. 9, T. 1, R. 2	125	5 or 6	Loess, 80 feet; sand and gravel, 45 feet.
Burdick, A	Sec. 31, T. 1, R. 1	725	.....	No record.
Aufderheide, J. H	Sec. 13, T. 2, R. 4	98	.....	Water in coarse sand 3 feet thick.
Werner, Phil	Sec. 11, T. 2, R. 4	106	.....	No record.
Thiernan, H. B	Sec. 5, T. 2, R. 4	105	.....	Do.
Cornell, E. M	Sec. 6, T. 2, R. 2	20	5	Do.
Dufur, William	Sec. 1, T. 2, R. 2 W	27	10	Soil, sand, and gravel; at base of limestone bluff.
Wheeler, Jennie E	Sec. 4, T. 2, R. 1 W	71	36	Soil, shale, slate, flint.
Houser, Joseph	Sec. 2, T. 2, R. 1 W	100	18	Soil and sand, 10 feet; lime rock, 13 feet; blue shale with occasional hard beds, 75 feet; sandstone, 2 feet; poor supply.
Thiernan, W	Sec. 25, T. 3, R. 4	36	.....	Soil and loess, 20 feet; sand, 4 feet; coarse sand and gravel 12 feet.
Meyer, John	Sec. 21, T. 3, R. 4	120	.....	Loess, sand.
Elting, Charles	Sec. 18, T. 3, R. 3	147	.....	No record.
Scharatt, H. J	Sec. 8, T. 3, R. 3	112	.....	Do.
Upton, R. B	Sec. 4, T. 3, R. 3	92	.....	Do.
Schainost, Fred	Sec. 36, T. 3, R. 1 W	55	22	Sand, shale.
Hergott, Joseph	Sec. 25, T. 3, R. 1 W	32	2	Soil, 2 feet; clay, 8 feet; limestone and beds of clay, 22 feet.
Knape, O	Sec. 36, T. 3, R. 1 W	173	40	Soil, limestone, shale, sandstone.

Representative wells of Thayer County, Nebr.—Continued.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Hergott, Joseph	Sec. 35, T. 3, R. 1 W	150	18	Soil and clay, 5 feet; limestone with clay beds, 25 feet; shale to water in sandstone.
Bulin, A	Sec. 12, T. 3, R. 1 W	192	16	Soil and loess, 70 feet; limestone and clay to water in sandstone.
Dill, M. C	Sec. 7, T. 3, R. 2	70	7	Soil, 2 feet; loess, 61 feet; coarse sand and gravel, 7 feet.
Mahoffy, S. A	Sec. 14, T. 4, R. 4	80	.....	Loess, 30 feet; sand, 50 feet.
Wright, G. N	Sec. 36, T. 4, R. 4	94	.....	No record.
Bice, A. W	Sec. 24, T. 4, R. 3	84	8	Do.
Bushnell, Scott	Sec. 22, T. 4, R. 2	90	.....	Loess, 40 feet; sand, 50 feet.
Thompson, George	Sec. 11, T. 4, R. 2	85	.....	Soil and gumbo, 2 feet; loess, 18 feet; sand and clay, 65 feet.

JEFFERSON COUNTY.

The occurrence of underground water in Jefferson County is very irregular. In localities where the Graneros and Carlile shales are not overlain by water-bearing sand or gravel, the only alternative is to drill or bore into the Dakota sandstone, which supplies water in abundance, indeed, but varying in quality with the locality. In localities where the Graneros shale extends high up the valley slopes, good wells are rare, unless they extend through the shale into the Dakota sandstone. Some of the wells in this sandstone yield good water, but in many of them it is saline, examples of the latter being found at Gladstone and at a number of points between Powell and Steele.

In much of the county a thick deposit of Quaternary sands and gravels beneath the loess affords an abundance of water at depths varying from 70 to 160 feet. These sands and gravels are extensively developed in the uplands east of Fairbury, about Jansen, and north of the Big Sandy.

At Powell the first water in the alluvium lies within a few feet of the surface. At Fairbury, on the bottom lands, where Pleistocene and alluvial sands blend so that it is difficult to distinguish between them, they carry a large supply of water, reached by wells varying from 30 to over 100 feet in depth, the deeper wells being on the valley slope. At Endicott and Steele the supply comes from the Dakota sandstone and alluvium. About Jansen wells usually derive their water from Quaternary sands, but the deepest one extends a short distance into Dakota sandstone.

Numerous springs, some of considerable size, occur among the deep ravines along Rose Creek and other tributaries of Little Blue River. A hotel in Steele is supplied by spring water. A general seepage into Big Sandy and Little Blue River from the Dakota formation and Pleistocene sands occurs in the northwestern part of the county.

Representative wells of Jefferson County, Nebr.

Owner.	Location.	Depth of well.	Depth of water.	Materials penetrated.
		Feet.	*Feet.*	
Wimer, Eli	Sec. 31, T 1, R. 1 E	15	7	Soil, clay, limestone, clay.
Lobaugh, J. M	Sec. 32, T 1, R. 1 E	.....	.....	Rock, clay, soapstone.
Simmons, James	Sec. 28, T. 1, R. 1 E	30	20	No record.
Shepherd, Alex	Sec. 16, T. 1, R. 3	68	9	Soil, sand, gravel.
Boggs, J. O	Sec. 3, T. 1, R. 3	81	45	Soil, 4 feet; loess, 10 feet; Dakota clay, 66 feet; sand, 1 foot.
Connell, John	Sec. 19, T. 2, R. 1 E	281	.....	Soil and clay, 35 feet; sand, 65 feet; slate, soapstone, and a little coal.
Carmony, F. A	Sec. 14, T. 2, R. 2 W	90	6	Loess, 2 feet; sand, 16 feet; clay, 3 feet; sand, 19 feet.
Bodarge, William	Sec. 21, T. 2, R. 2	135	30	Soil, 20 feet; lime rock, 30 feet; shale, 60 feet; soapstone, 20 feet; on sandstone with water.
Wells, Ed	Sec. —, T. 2, R. 3	310	175	Loess and soil, 60 feet; sand and gravel, 70 feet; clay, 180 feet; gravel and sand; water.
Spicer, J. R	Sec. 10, T. 2, R. 4	40	18	Loess and sand.
Landkamer, Geo	Sec. 21, T. 3, R. 1	18	7	Hard pan.
Weise, John	Sec. 4, T. 2, R. 4	125	20	Loess, except 5 feet; black clay and 3 feet glacial sand.
Akin, A. M	Sec. 32, T. 3, R. 1	100	16	Loam and limestone, 20 feet; slate, 64 feet; sand and sandstone, 16 feet.
Schroeder, J. H	Sec. 30, T. 3 N., R. 1 E	150	50	Soil, 15 feet; slate, 35 feet; limestone; water in quicksand.
Moles, D. P	Sec. 26, T. 3, R. 2	110	40	No record.
Pickens, Wes	Sec. 35, T. 3, R. 2	148	70	Do.
Janert, William	Sec. 35, T. 3, R. 2	227	70	Do.
In town (Jansen, Nebr.).	Sec. 34, T. 3, R. 3	160	.....	Soil, 4 feet; loess, 100 feet; glacial sand, 56 feet.
Wrighley, Jas	Sec. 10, T. 3, R. 4	115	20	Quicksand.
Public well (Harbine, Nebr.).	Sec. 28, T. 3, R. 4	122	4	Loam, except 3 feet of sand at bottom.
Woodman, Art	Sec. 30, T. 4 N., R. 1 E	62	4	Loess, 2 feet; sand, 14 feet; clay, 8 feet; sand.
Frost, Eph. (owner, Newell, H. J.).	Sec. 27, T. 4 N., R. 1 E	.....	9	No record.
Hellwig, Frank	Sec. 26, T. 4 N., R. 1 E	96	.....	Do.
Glenn, Mary	Sec. 23, T. 4, R. 1	60	30	Loam and sand, 40 feet; slate, 2 feet; sand, 13 feet; lime rock, 1 foot; sand, 4 feet.
Wolfe, Cyrus	Sec. 32, T. 4, R. 4	130	6	Soil, 8 feet; loess, 80 feet; glacial drift, 42 feet.

WATER POWER.

GENERAL STATEMENT.

Only a brief statement as to the location and maintenance of water-power sites can be given in this report. The water-power prospects in the Republican Valley region are more important than is generally supposed, the plants now in operation employing only a portion of the total power available. The power is now used principally by flour and grist mills and to some extent for electric-light plants. Climatic conditions are an important factor in the industry, for the winters are so open as to permit the use of power during the coldest months. In the western counties there are many sites with limited power along small spring-fed streams, but farther east, where the run-off is greater and streams are supplied liberally from underground sources, greater and more lasting powers are found.

As yet the demand for power is not great. Much grain is now shipped outside the region which might be milled in the valley were it not for the lower shipping rates for wheat than for flour. As a result of this condition the product of most mills is only for local use and but little power is required to grind it. With increasing population, however, and the usual high price of fuel there will be an increasing need for water power.

The power sites are in the basins of Republican and Little Blue rivers and the more favorable locations are on the strongest tributaries. On these the fall or grade per mile is somewhat greater than on the rivers and short dams impound enough water for the mill pond at small expense. Along the rivers dams need to be longer, and consequently are more expensive to construct and to maintain. Republican River usually dries up in the western counties during a part of the summer, a condition which prevents successful development of water power there. Farther east the constant flow affords ample supply, but occasional high waters are apt to cut a new channel to one side of the dam or to do it much damage. This is especially true where the dam lies on sandy alluvium.

POWER SITES IN THE REPUBLICAN VALLEY.

Several years ago water powers were in operation on Republican River at Oxford, Alma, Franklin, and Red Cloud. Periods of drought and high water brought about their disuse, except at Red Cloud, where the mill was burned. Three powers are now operated along the Republican, near Arapahoe, at Orleans, and at Superior. The dam at Superior is shown in Pl. XII, *B*.

Powers might be obtained at reasonable cost at several places on tributaries of the Republican. The flow of Buffalo Creek, in Dundy County varies but little during the year and continues all winter. The stream gages about 10 second-feet with a fall of about 15 feet per mile. Power for use about the house has been employed by Mr. N. J. Allen, who diverts a part of the flow in his irrigation ditch over a small wheel which can be connected to either a churn, washing machine, or grindstone. Aside from this the power of Buffalo Creek is not utilized, and at present there is little demand for it. Rock Creek is nearly as strong as Buffalo Creek and could be made to yield small powers.

Several small powers are available on Frenchman River. Those at Wauneta and Palisade, both outside the area treated in this report, are of most value, the former utilizing a natural fall of 7 feet and an artificial fall of over 1 foot. Redwillow Creek has a dam and mill.

A successful power, located on Medicine Creek, at Cambridge, runs

a mill all the year and practically night and day. A site now not in use is on Big Muddy Creek, northwest of Arapahoe. There are 3 dams in the Sappa-Beaver Creek basin—at Stamford, Beaver, and Wilsonville. A mill formerly operated in the Sappa was moved to Superior, where it is now running. Small spring-fed streams afford sufficient water for small powers at Naponee, Bloomington, and Franklin.

POWER SITES IN THE LITTLE BLUE RIVER BASIN.

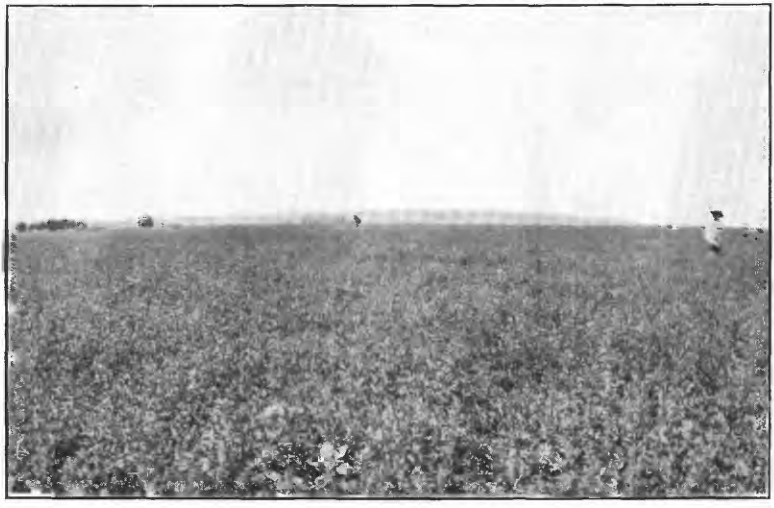
There are 8 dams now in the Little Blue basin, while another, formerly located near the abandoned town of Meridian, was destroyed by high water.

Most dams in the basin have been damaged by high waters and on that account their maintenance is expensive. The most trouble has been experienced at Hebron and Fairbury. At the former place the river is held in position at heavy expense, because the stream has a strong tendency to cut across the bottom just east of the dam and mill. At Fairbury most of the old dam has been replaced recently by a concrete dam, which it is thought will better cope with high waters. If a dam on the Little Blue is made too high the flow of the stream is diverted over the low banks and the sandy flood plain at times of high water, threatening not only the abutment of the dam but other property as well. Dam sites now in use in this basin are at or near Steele, Fairbury, Alexandria, Hebron, Deweese, Oak, and Blue Bluffs.

IRRIGATION.

The principal irrigation now in operation in the Republican Valley region is on the valleys and bench lands, though in some cases the ditches extend out on the lower adjacent valley slopes. The extent of irrigable land is moderately large, but the supply of water is not adequate for reclamation of the entire area. In the eastern and central counties the average rainfall is sufficient for the growth of crops without irrigation, except in an occasional season. At a number of places in the Republican Valley region ditches have been constructed for use during drought, but have been allowed to get out of order during rainy seasons. Furthermore, the principal supplies are at the headwaters of streams, and loss of water by evaporation and seepage during transmission into the broader valleys is great.

It has been found that irrigation along the main valley of the Republican in the western counties is practicable only near the headwaters and below the mouths of some of the strong tributary streams. The best results in that region are obtained between Haigler, Nebr., and Laird, Colo. (see Pl. XIII, *A*), about Benkelman, and along the Frenchman, near Culbertson.



A. IRRIGATED ALFALFA FIELD NORTHWEST OF HAIGLER, NEBR.

B. BUR-OAK GROVE NEAR ENDICOTT, NEBR.

According to the State engineer about 35,000 acres are under irrigation in the region described in this report. The total length of ditches is about 130 miles, of which apparently less than one-half was operated in 1904. The number of acres irrigated by counties decreases from west to east. The counties including most of the area are Dundy, 17,415 acres; Hitchcock, 13,070; Redwillow, 3,935. In 1904 the area was much less.

AGRICULTURAL RESOURCES.

GENERAL STATEMENT.

The utilization of the part of the Great Plains where there is but little rainfall has been a subject of much study. Different methods have been employed from time to time, but they have failed to bring the results which their promoters had hoped to attain. At times stock raising has been thought to be the only industry adapted to the sand hills and dry uplands, while again it has been thought that grain crops might be grown over a large portion of the area. The successes and failures in the unfavored sections have been varied. Settlement has increased and decreased in periods corresponding with the amount of rainfall.

The early attempts at forestation by planting "tree claims" gave poor results, probably because the planting was done crudely and groves were not properly cared for. Very few of the thousands of groves thus started have survived, but a few successful ones show that, if carried on with greater care and with species suited to the climate, good results may be attained.

The introduction of drought-resisting and early-maturing crops is thought by some to be an important factor in reclamation. The crops thus far grown are the forage crops and varieties of oats and wheat.

Dry-farming methods adapted to the rainfall are being promoted at a number of places. The aim is to hold as much of the water in the soil as is possible by proper tillage. The main enemy to soil storage of water is evaporation, and by maintaining a mulch the loss in that manner is reduced to a minimum. To what extent this method, commonly called the Campbell system, will aid in reclamation is not fully proved. It is promoted by the Chicago, Burlington and Quincy Railroad, apparently with good results, and promises to become valuable.

SOILS.

Agriculture is by far the most important resource of the region, but its results are greatly affected by the local variations in climate, ground water, and soils. The rainfall and ground-water conditions have been described above, but the many different kinds of soils have

not been differentiated. In general, the distribution of the different types corresponds with that of the geologic formations, but minor variations exist, often of considerable importance in plant growth. There are in the region three fairly distinct agricultural provinces—the loess table-lands, the alluvial bottom lands, and the sand hills.

The loess plains of the wide table-lands between the valleys occupy the greater part of the area treated in this report. Where the streams have cut through the loess, the various underlying formations appear with soils of different kinds extending in narrow belts along the valley slopes. Glacial soils, which occur mostly in Jefferson County, are clayey or sandy, with an admixture of pebbles and bowlders. Soils on or below outcrops of Dakota sandstone are sandy, but in places are clayey or ocherous. Extensive alluvial soils occur along the rivers and their tributaries. They contain a high per cent of silt or sand and usually a small proportion of clay. Soils formed from the Cretaceous shales and chalk rock extend along some of the valley slopes not covered by loess or alluvium, and are usually of bad quality for agriculture.

In the sand-hill region loose sandy soil of the dunes consists mainly of quartz sand with but little clay, while in the basins and dry valleys there is an admixture of some humus and considerable clay.

The table-land soil is sandy, and may grade into sand hills on one side and into the so-called plains marl or western loess on the other. The talus slopes below ledges of Tertiary rock are mostly sandy or gravelly.

CROPS.

NATIVE GRASSES AND THEIR UTILIZATION.

The region contains a large number of grasses, the distribution of which is controlled by topographic and hydrographic conditions. The highest and heaviest growth is found on bottom lands and eastward over the valley slopes. The drier uplands are quite thickly matted with "short grass." In the sand-hill region the grass covering mostly is thin, except in the dry basins and valleys. In this region there is often much sagebrush and other herbaceous plants, having but little grazing value. In all the counties the meadow grasses are cut for hay, with a total product estimated at 100,000 tons per year.

Three species of blue-stem grasses are of frequent occurrence: *Andropogan furcatus* is abundant on the bottom lands eastward; *Andropogan scoparius* (bunch grass) is widely distributed, extending over bottom lands, onto ridges, and throughout the sand hills; *Andropogan halli* is found on sand dunes and ridges.

Under the name buffalo grass a number of species are usually included. One of these, *Bulbulis dactyloides*, is widely spread over

the dry uplands, and extends as patches in dry basins and valleys in the sand hills. It is very nutritious, and when not too much leached by fall rains serves as one of the best winter foods. The grammas are generally known as buffalo grass, with which they correspond somewhat in distribution and values for grazing. One of them, *Bouteloua oligostachya*, is perhaps the most important dry upland grass. A larger species is more often cut for hay.

The uplands are occupied nearly exclusively at places by wheat grasses, which are not so desirable as the buffalo and grammas. *Stipa conata* is a common species.

CULTIVATED FORAGE CROPS.

Among the cultivated forage crops alfalfa is first in importance. It is most successfully and extensively grown throughout the region on low bench lands, where it has become an important resource. Three or four crops are cut each year, and are used extensively as swine pasture and for hay. Some of the largest fields are near Indianola, Beaver, and Republican. In the counties farthest west irrigation is employed where water is accessible; a typical irrigated field is shown in Pl. XIII, *A*. On the uplands about two cuttings are harvested each year. In the sand hills the crop is now grown at a few places where ground water rises close to the surface.

Timothy and clover are not very extensively grown. The principal forage crops raised during drought times and on the driest lands are sorghum, cane, millet, and hungarian. These require more labor in cultivation than alfalfa, and hence are less popular crops.

The following table, showing the acreage of cultivated forage crops, is compiled from the Nebraska Labor Bureau Report for 1903:

Area of cultivated forage crops.

[Acres.]

County.	Alfalfa.	Millet and hungarian.	Sorghum and cane.
Dundy	618	2,021	5,403
Hitchcock	533	402	10,188
Redwillow	6,956	3,617	8,416
Furnas	10,359	2,540	10,785
Harlan	11,683	1,959	2,262
Franklin	5,882	1,229	2,433
Webster	10,168	2,217	4,396
Nuckolls	8,178	2,544	2,525
Thayer	4,366	1,451	2,271
Jefferson	2,979	3,706	2,405
Total	61,742	21,686	51,084

GRAIN CROPS.

The principal grains cultivated are corn, wheat, oats, and rye. Barley is raised to some extent west of Franklin County. Winter wheat is much more common than spring wheat, especially in the

eastern part of the region. The accompanying table, which is based on the labor bureau report, shows the number of bushels of the principal cereals produced in each county in 1903:

Quantity of cereals produced in 1903.

[Bushels.]

County.	Corn.	Wheat.	Oats.	Rye.
Dundy	806,067	40,970	6,559	13,955
Hitchcock	668,640	446,855	5,778	172,603
Redwillow	1,561,681	1,555,870	24,412	459,253
Furnas	1,986,544	1,690,314	76,434	323,125
Harlan	1,966,456	1,300,6?0	195,397	256,481
Franklin	1,961,008	1,066,530	401,131	48,875
Webster	2,272,956	1,032,475	452,231	54,725
Nuckolls	2,977,652	923,450	485,619	72,484
Thayer	3,212,131	1,018,094	1,025,303	58,119
Jefferson	2,748,461	727,240	4,073,478	16,350
Total	20,161,596	9,802,488	6,746,342	1,475,968

FRUIT RAISING.

Numerous wild fruits grow along ravines and in canyons. Cultivated fruits—such as peaches, plums, and cherries—are marketed from a number of large orchards. The W. T. Collins orchards, located on bench lands 1 mile west of Beaver, contain 1,300 peach trees, which were heavily loaded in 1904.

On the place of James Drummond, 6 miles northwest of Haigler and three-fourths mile from the Colorado line, is a successful orchard and vineyard under irrigation. When visited, cherry trees had averaged between 3 and 4 bushels of fruit each, and the apple trees were in promising condition. Mr. N. J. Allen has raised fine peaches and plums by irrigation on a sand-hill point 4 miles east of Haigler. These are but types of a large number of orchards that might be named.

SUGAR BEETS.

Beets are successfully grown under irrigation on the bench lands of the western counties, but the best crops are raised in the Frenchman Valley above Culbertson and at a number of points along the Republican. The following table shows the acreage of beets by counties and the extent of the crop for 1904:

Acreage planted in beets, 1904, in southern Nebraska.

County.	Acres.	County.	Acres.
Dundy	92	Webster	32
Hitchcock	686	Nuckolls	1
Redwillow	690	Thayer	4
Furnas	96		
Harlan	32	Total	1,671
Franklin	38		

STOCK RAISING AND DAIRYING.

Stock raising and dairying are closely related to the grass growth, forage, and grain crops already described. The largest stock ranches are located in the thin and short grass regions where most of the land is cheap, and, owing to its subhumid condition, is better adapted to grazing than to other agricultural purposes. The grasses cure on the sod during the time of diminished rainfall in the late summer and fall months and afford pasturage all winter except at times of deepest snowfall. Thousands of cattle and horses "rustle" during the winter without other food. Some winters this lack of care for stock has resulted in heavy losses, especially in former years when most cattle were not provided for; during heavy snowstorms large numbers died more from hunger than from cold. Of recent years winter feed usually is provided for stock during times of exceptionally severe weather and the percentage of loss is greatly diminished.

The western part of the region to which this report relates lies in that part of the Great Plains which is generally known as the "cattle country," yet the number of animals per square mile in the western counties is less than it is farther east where more corn is grown. The day of the open range has passed; now large areas are fenced, in the grazing counties, and controlled by ranchmen.

In the counties farthest east stock are pastured on the roughest land during the grazing months and fed on rough feed in winter. Swine are raised cheaply and in large numbers where alfalfa is most extensively grown.

Dairying has become one of the important industries throughout the region and is successful during both drought and humid years. The cream is shipped from numerous stations to large creameries.

The accompanying table shows the number and distribution of the principal farm animals for 1904:

Number and distribution of farm animals for 1904.

County.	Cattle.	Hogs.	Horses and mules.
Dundy	15,677	5,002	2,708
Hitchcock	13,995	4,254	3,549
Redwillow	17,663	16,566	4,501
Furnas	33,238	29,688	11,307
Harlan	26,402	21,888	8,546
Franklin	24,926	25,876	7,732
Webster	33,690	34,690	10,089
Nuckolls	22,000	26,939	6,865
Thayer	29,202	26,586	11,487
Jefferson	26,054	27,218	8,303
Total	242,947	218,707	75,087

TIMBER.

Early settlers and prairie fires destroyed much of the natural tree growth, which appears to have been more prevalent at the time of the country's first occupation than it is now. However, the traveler while passing along the open valleys is apt to underestimate the amount of timber growing in the region as, for the most part, it is confined to ravines and the rough lands adjacent to the larger valleys.

Cottonwoods are found both in groves and isolated on all valley bottoms. Along the Frenchman Valley and in the canyons of northeastern Dundy County there are cottonwood trees 2 to 3 feet in diameter, and one located 7 miles northwest of Fairbury is over 6 feet in diameter. Willows, represented by one or more species, are found in all valleys of any considerable size.

Bur oaks follow up and cover the sandy slopes in Jefferson County, and occur westward along the Little Blue and in the lower course of the Republican Valley (see Pl. XIII, *B*). Elms are found in largest numbers on the bottom lands in Jefferson, Thayer, and Nuckolls counties, but extend westward on the alluvium to Dundy County. Parts of Sappa Valley were formerly covered with large elms. Walnut trees of large size grow in the valley bottoms as far west as Red Cloud. A tree nearly 3 feet in diameter is reported south of Naponee.

Ash and boxelders are scattered among other species in the valley portions of the region. Straggling cedars remain on the bluffs of Webster, Franklin, and Nuckolls counties, and a small pine is reported as having been found in a ravine south of Bloomington. The tree growth is utilized for firewood, posts, and lumber.

INDEX.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 216.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

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1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.

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THE DIRECTOR,
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AUGUST, 1907.

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